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Relationships Between Microbial Parameters and Soil Properties in a Hydrophobic Spolic Technosol

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Abstract

Data on microbiology of water repellent (hydrophobic) soils in Bulgaria are scarce. This work aimed to find out relations between microbiological indicators, hydrophobicity level and other soil properties in a Spolic Technosol. Samples from 0-10 cm and 10-20 cm soil depth of a fly ash reclaimed soil covered with tuft vegetation and located near Obruchiste area were collected. Main microbiological (basal respiration - BR, microbial biomass carbon content -Cmic, amount of main microbial groups –CFU), chemical (organic carbon, available N, P and K contents) and physical (hydrophobicity level, moisture, sand and clay contents) properties were determined. It was found that the Technosol was hydrophobic in most of the monitoring points. Half of the samples were severely or extremely hydrophobic (assessed by water-drop-penetration time) and the hydrophobicity level was higher in the subsurface layer. The Spolic Techosol under tuft vegetation was characterized with low numbers of heterotrophic bacteria, actinomycetes and oligotrophic microorganisms ($1-40 \times 10^2$ CFU/g) at 0-20 cm depth. As a whole, low BR rate (0.51-5.43 mg CO₂/g/ 24h) and low Cmic values (2.37-18.18 mg C/100g) were established for both layers. Weak relationships of microbial parameters with organic carbon, humic acid, fulvic acid and clay contents were noticed in this soil. Significant correlations of the amount of fungi and actinomycetes with available nutrient and moisture contents were found.

In general, a trend of positive relationships of fungi, actinomycetes and cellulolytic microorganisms with soil hydrophobicity was established. The relative parts of fungi and actinomycetes increased in the hydrophobic samples comparing to non-hydrophobic ones. Microbial biomass carbon tended to increase with increasing the hydrophobicity level. Data pointed on close positive relationships of microbial parameters studied with the hydrophobicity in this Technosol.

Our results add new information to the monitoring study of hydrophobic Technosols from Maritsa-Iztok coal-mining region (Bulgaria).

Key words: soil hydrophobicity, Spolic Technosol, basal respiration, microbial biomass, microbial amount

Introduction

Hydrophobic (water repellent) soils are characterized by reduced water retention and infiltration in depth. High hydrophobicity may lead to increased soil erosion and nutrient loss and may cause negative impact on plant growth and crop production (Doerr et al., 2000).

Scientific literature indicates complex interactions of water repellency with soil properties. In most cases soil organic matter, and especially its quality, is related to the formation of hydrophobic properties (Buczko et al., 2005; Buczko et al., 2006; Mataix-Solera, et al., 2007). Among large numbers of chemical and biological factors, Lozano et al. (2013) revealed the extractable lipid fraction of soil organic matter as a principal factor for hydrophobicity in forest soils. These authors found that fungal biomass was related to soil organic matter content which led to the suggestion that water repellency under *Pinus* trees could be mostly influenced by fungi.

Microorganisms contribute to organic matter formation in soils and their possible role as a factor in hydrophobicity development received a lot of attention. Relations between hydrophobicity and microbial soil properties have been investigated for many years. Evidence for contribution of fungi (Rillig, 2005; Lozano et al., 2013) actinomycetes (Lozano et al., 2014) and bacteria (Morales et al., 2010) to soil water repellency were reported. Studies showed that hydrophobicity was caused by hydrophobic organic compounds originated mainly from plants and microorganisms (Atanassova, Doerr, 2010; Atanassova et al., 2014; Atanassova, Doerr, 2015; Mao et al., 2014) and produced during residue decomposition or as a response to water stress conditions (Morales et al., 2010). Other microbial mechanisms contributing to hydrophobicity formation could be the production of hydrophobic substances and a reduction of soil porosity by fungal hyphae, gaseous and other by-products released in the process of residue mineralization (Morales et al., 2010).

In the first studies, water repellency was mostly associated with soil fungi which take part in organic matter decomposition (DeBano, 2000). Recently, a strong dependence of hydrophobicity with microbial community composition has been suggested (Lozano et al., 2014). DeBano (2000) revealed a connection with microbial hydrophobic exudates. Bodi et al. (2013) linked variation of hydrophobicity to the spatial variability of organic matter content and fungal biomass. In some studies, strong correlation between fungal biomass (ergosterol) and the level of hydrophobicity in agricultural soils (Feeney et al., 2006) was found.

Microbial effects in water repellency of different soils are still not clear (Zheng et al., 2016). Regarding Technosols, few studies on relationships between hydrophobicity, microorganisms and lipids are available (Petkova et al., 2017; Atanassova et al., 2017; Nedyalkova et al., 2018; Atanassova et al., 2020). The present study aimed to find out relations of microbiological indicators with hydrophobicity level and other soil properties in a Spolic Technosol under tuft vegetation.

Materials and Methods

The experimental site was located in Maritza-Iztok open cast coal mine region at the Obruchishte-3 spoil created more than 30 years ago. The plot consisted of loam Pliocene overburden sediments (yellowish-green and greyish-green clays) containing irregularly distributed coal particles. The soil is classified as Spolic Technosol (IUSS Working Group

WRB, 2015). To ameliorate soil acidity fly ash (obtained after coal incineration of in the thermal power station) had been added to the clay materials. The surface was covered by tuft vegetation. A grid of Δ^2m of $\sim 40m^2$ was constructed and samples at six points were taken from 0-10 and 10-20 cm depth using a 3 cm wide and 25 cm long core sampler.

Soil hydrophobicity (water repellency) was determined by measuring the time for water drop penetration (WDPT) according to Doer et al. (2002) and the level of hydrophobicity was classified as: wettable or hydrophilic ($<5s$), slight (5-60 s), strong (60-600s), severe (600-3600s) and extreme ($>3600s$) (Dekker, Ritsema, 1996).

The amount of microorganisms was determined by plate counts technique on selective agar media. Heterotrophic bacteria were cultivated on Nutrient broth agar, actinomycetes – on starch-ammonium agar medium, saprotrophic fungi – on Czapek's agar medium, cellulolytic microorganisms – on Hutchinson's medium, oligotrophic microorganisms – on 1/100 diluted Nutrient broth (Grudeva et al., 2007). Microbial colonies formed were counted after incubation at 28°C and data were presented as colony-forming units per gram of absolutely dry soil (CFU/g).

Basal respiration of soil (CO_2 evolution) was measured in the laboratory after sieving (2 mm mesh) and removing roots and residues from the samples. The samples were adjusted to 60% moisture content and incubated 24 h at 25°C in tightly closed vials, following the procedure of Alef (1995). After basal respiration (BR) measurement, glucose was added and samples were incubated for another 4 hours at 22°C to determine microbial biomass carbon (C_{mic}). The CO_2 evolved was determined by titration. Microbial carbon was calculated according to the equation proposed by Anderson, Domcsh (1978).

Soil chemical properties - total organic carbon (TOC), humic acids (HA), fulvic acids (FA), available nitrogen (N), phosphorus (P) and potassium (K) contents, and physical properties – hydrophobicity level (WDPT), moisture, sand and clay contents, were determined by conventional methods as described in Atanassova et al. (2018). Here we report their relations with microbial parameters only.

To examine relationships between microbial parameters and soil properties Pearson correlation coefficients were calculated. Multiple comparison between means was made by one-way ANOVA followed by Games-Howell post hoc test for unequal variances ($P<0.05$). Data were processed using SPSS 22 for MS Windows.

Results and Discussion

Soil hydrophobicity level in monitoring points differed among samples and between soil depths. Two of the samples in the surface layer were hydrophilic, three samples possessed slight hydrophobicity, two samples were strongly hydrophobic, one was severely hydrophobic and four samples possessed extreme hydrophobicity. WDPT values ranged between 8-11636 s for both layers. In general, higher hydrophobicity level in the 10-20 cm layer was found (Fig. 1).

Data on spatial variation of soil hydrophobicity in non-vegetated and *Pinus nigra* afforested Technosols from Maritza-Iztok mining region were reported in the study of Ivanov et al. (2019) in which extreme hydrophobicity was registered in the surface 0-10 cm layer of the soil under *Pinus* trees. The hydrophobicity variation in Spolic Technosols was related to the heterogenic composition of the soil and to randomly distributed coal particles and ashes in

different layers (Atanassova et al., 2018). Similarly, variations in hydrophobicity (water repellency) for reclaimed lignite mine soils (Atanassova et al., 2017; Gerke et al., 2001) and for forest soils (Lozano et al., 2013) were reported.

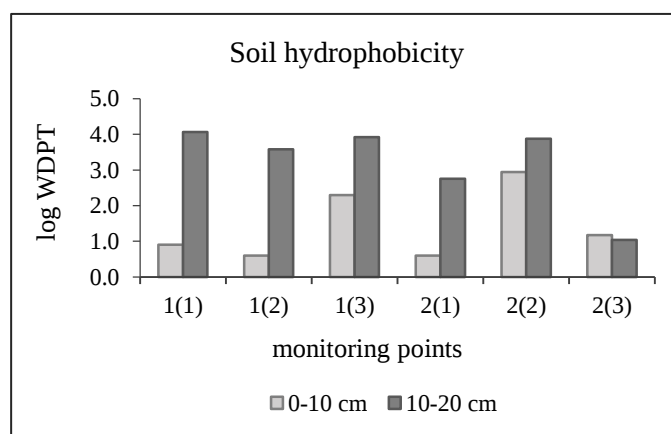


Fig. 1. Soil hydrophobicity variation among monitoring points and soil depth in the Spolic Technosol from Obruchishte area in the Maritsa-Iztok coal mining region.

The heterogenic properties of the Technosol determined variations in microbial parameters. The amount of microbial groups differed depending on sampling points and soil depth. For both soil layers, microbial numbers varied as follows: heterotrophic bacteria - $2.8\text{--}18.60 \times 10^2$ CFU/g, actinomycetes - $0.53\text{--}17.87 \times 10^2$ CFU/g, saprotrophic fungi - $4.5\text{--}24.6 \times 10^2$ CFU/g, cellulolytic microorganisms - $12.53\text{--}37.87 \times 10^2$ CFU/g and oligotrophic microorganisms - $2.07\text{--}34.87 \times 10^2$ CFU/g (Fig. 2).

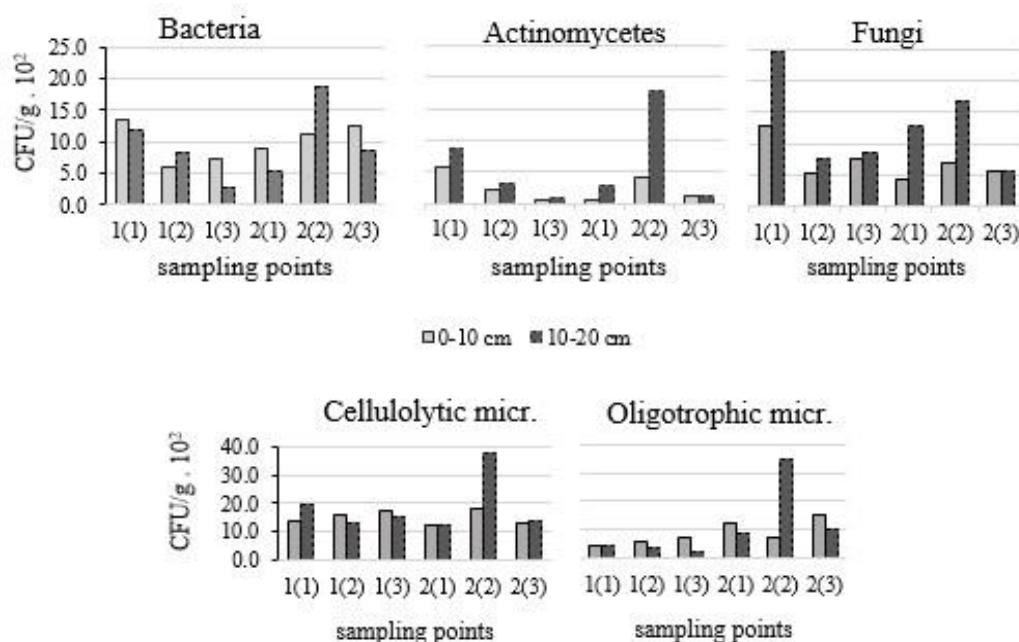


Fig. 2. Amount of microbial groups studied in different monitoring points (0-10 cm and 10-20 cm depth) in the Spolic Technosol.

In general, microbial amount in the Technosol was low comparing to native soils where up to 10^4 - 10^8 CFU/g could be found. Unfavorable physical properties and the scarce vegetation (tufts) of this soil are among reasons for the low microbial population size.

Fungi and actinomycetes had higher numbers in the 10-20 cm layer (Fig.2) in which higher hydrophobicity levels (Fig. 1) were detected, as well. The relative share of fungi and actinomycetes was higher in water repellent (hydrophobic) soil samples of both layers comparing to non- hydrophobic samples (Fig. 3). Data suggested close relationships of those microbial groups with soil hydrophobicity. In the scientific literature, fungi, actinomycetes and bacteria are often associated with hydrophobic soil properties (Rillig, 2005; Morales et al., 2010; Lozano et al., 2014). It is proved that microorganisms are able to produce hydrophobic substances as survival mechanism in response to recurring water stress (Morales et al., 2010). These substances (hydrophobins) coat soil particles and reduce soil porosity thus inducing low water retention and preventing water flow into the soil.

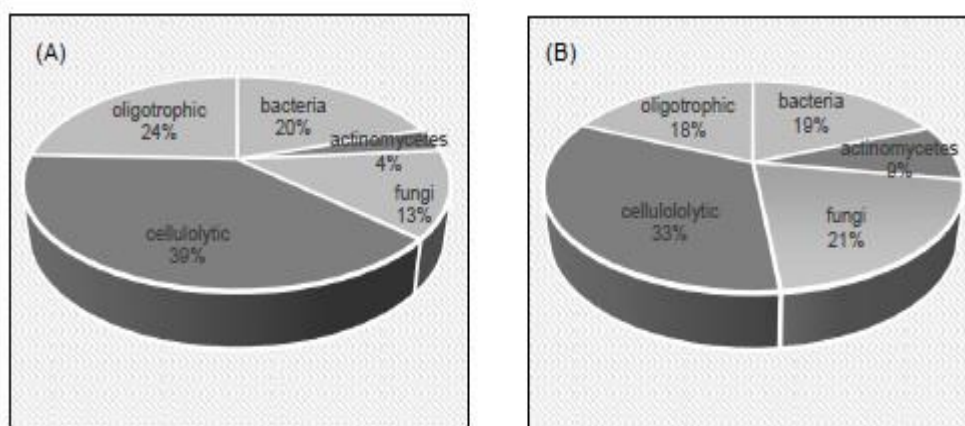


Fig. 3. Relative part of microbial groups in non-hydrophobic (A) and water repellent (hydrophobic) (B) samples in both layers (0-20 cm depth) of the Spolic Technosol.

Similarly to microbial numbers, low basal respiration and microbial biomass carbon values were determined in the Technosol. Basal respiration rate ranged from 0.51 to 5.43 mg CO₂/100g/24h. Microbial biomass carbon varied between 2.37 and 14.18 mg C/100g. As a whole, higher respiration and microbial biomass values were registered in hydrophobic samples comparing to hydrophilic ones (Fig. 4). Data obtained confirm findings for another Technosol from this area (Nedyalkova et al., 2018).

There was an increasing trend of microbial biomass carbon with increasing the hydrophobicity level. Some authors have found positive correlation between fungal biomass (ergosterol) and soil hydrophobicity (Young et al., 2012) but others obtained no clear trends for relationships between them (Feeney et al., 2006). Obviously, other factors (SOM, particle size distribution, water content) also influence those relationships and the causes of soil hydrophobic properties are more complex (Zheng et al., 2016).

Significant linear relationships for some microbial parameters and soil properties were determined. For 0-10 cm layer, cellulolytic microorganisms were significantly positively correlated with WDPT ($r=0.975^*$). For 10-20 cm layer, very high positive correlation between

fungi and actinomycetes ($r=0.975^*$) and negative correlation of actinomycetes with moisture content ($r=-0.960^*$) were detected.

Considering all samples in both layers, a trend of positive relationships with WDPT for fungi ($r=0.746$), actinomycetes ($r=0.541$) and cellulolytic microorganisms ($r=0.691$) was found. The numbers of actinomycetes ($r=0.866^{**}$) and fungi ($r=0.798^*$) were significantly positively correlated with available phosphorus content and between each other ($r=0.937^{**}$). Negative correlations of actinomycetes with available K ($r=-0.738^*$) and moisture ($r=-0.777^*$) contents were registered. Results obtained pointed that fungi and actinomycetes were highly influenced by soil properties in this study.

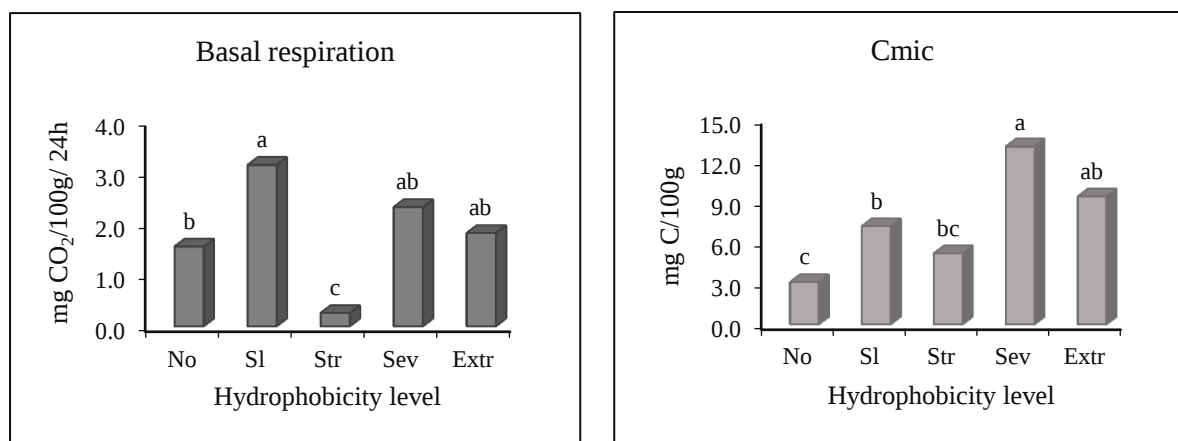


Fig. 4. Basal respiration rate ($\text{CO}_2/\text{sample}$) and microbial biomass carbon content ($\text{Cmic}/\text{sample}$) in different hydrophobicity level samples (No - non-hydrophobic; hydrophobic: Sl- slight, Str- strong, Sev- severe, Extr -extreme) in the Spolic Technosol. Different letters above columns show significant differences between values.

Basal respiration was in positive correlation with oligotrophic microorganisms ($r=0.981^{**}$ for 0-10 cm layer, $r=0.628$ for both layers). Weak relationships of microbial parameters with organic carbon, humic acids, fulvic acids and clay contents were noticed in the reclaimed soil.

Conclusion

Most of the samples from the Spolic Technosol under tuft vegetation were hydrophobic (water repellent) and half of them possessed severe or extreme hydrophobicity. Higher hydrophobicity level in the 10-20 cm layer was registered. Microbial parameters studied were in close positive relationships with the hydrophobicity in this soil.

The Spolic Technosol was characterized with low levels of microbial numbers, basal respiration and microbial biomass carbon. The microbial parameters had weak relationships with organic carbon, humic acid, fulvic acid and clay contents due to the heterogenic properties of the reclaimed soil. The amount of fungi and actinomycetes was significantly correlated with nutrient and moisture contents.

Our results add new finding to the monitoring of hydrophobicity in coal and fly ash reclaimed Technosols from the region of the largest coal mine producing complex in South Eastern Europe (Maritsa-Iztok coal mines, Bulgaria).

Acknowledgments

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Determination of Magnesium Salinity in Belozem Region, Bulgaria

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Abstract

Salinisation is an important soil-forming process (primary or secondary), characterized by an excess of water-soluble salts and/or exchangeable sodium. The amount of exchangeable magnesium is also essential for the more detailed determination of the physico-chemical properties of saline soils. The determination of magnesium salinity is still a debatable issue, but there are already criteria in the literature for its estimation. The Belozem region is representative of Bulgaria for the processes of alkaline salinisation, but the presence and extent of magnesium salinity has not been determined. For this purpose, data from ten soil profiles and four criteria for determining magnesium salinity were used. In three of the profiles there is an increased content of exchangeable magnesium, which covers all four indicators of magnesium salinity, in three of the profiles the magnesium salinity is determined only in some horizons and in the other four cannot be clearly defined. The study also showed that the application of all four criteria is necessary in order to make a strong claim for the presence of magnesium salinity.

Keywords: alkaline soils, exchangeable sodium, exchangeable magnesium, magnesium salinity, salinisation

Introduction

Salinisation is one of the most widespread soil degradation processes on the earth and occurs mainly in the arid–semiarid regions. Climate changes in recent years strengthened the occurrence of salinisation processes. According to Tóth et al. (2008) salt-affected soil can be divided into five main groups: *Solonchak* with high amount of water-soluble salts; *Solonetz* with high alkalinity and high exchangeable sodium percentage (ESP); *Magnesium soil* with high magnesium (Mg) content in the soil solution; *Gypsiferous soil* with strong gypsum or calcium sulphate accumulation; *Acid sulphate soil* with highly acidic iron or aluminium sulphate accumulation.

In the World Reference Base (WRB, 2006) soil classification system, saline soils mainly occur in the Reference Soil Group of Solonchaks. However, some other Reference Groups may also have a salic horizon (indication of certain degree of salinisation) such as Histosols, Vertisols and Fluvisols. Sodic soils mainly occur in the Reference Soil Group of Solonetz. However, Solonetz may be associated with Histosols, Gleysols, Chernozems, Kastanozems, Vertisols and Solonchaks. In WRB (2015) Solonetz is soils with a high content

of exchangeable sodium, and in some cases also magnesium ions; having natric horizon with high content of exch. Na and in some cases, a relatively high content of exchangeable Mg and more exch. Mg plus Na than Ca plus exchange acidity (at pH 8.2) throughout the entire natric horizon or its upper 40 cm. Solonetz can be defined with supplementary qualifiers magnesian (mg) by an exchangeable Ca to Mg ratio of < 1 in the major part within 100 cm of the soil surface. Magnesium salinity is also mentioned by Valkov et al. (2004). According to them, the presence of magnesium in the soil-absorption complex maintains the salinity property and in some cases may lead to the formation of a separate soil type – magnesium Solonetz.

Although magnesium has been mentioned as a diagnostic criteria along with sodium, magnesium salinity has not yet been clearly defined and soils with high magnesium content are not separated as a single genetic order of soils. The role of magnesium in the formation of soil salinity has not been sufficiently clarified and this issue is considered debatable. According to Gogolev and Voloshin (1968) magnesium salinity is observed at exch. Mg content as a percentage of the sum of exchangeable cations (CEC) above 25%. According to unpublished data, Kavardzhiev proposes that magnesium saline soils should be defined as soils with a content of more than 65% of the amount of exch. Na and exch. Mg of exch. Ca (Trendafilova, 1997). Penkov et al. (2003) provide a classification scheme for estimating the parameters of exchangeable magnesium percentage (EMP) in clay soils divided into 5 classes from 16% to 42%, respectively, from a slight degree of saturation to super strong.

Magnesium is an essential element for plant growth and development. The availability of magnesium to plants depends on various factors: the distribution and chemical properties of the source rock material and its grade of weathering, site specific climatic and anthropogenic factors (Scheffer and Schachtschabel, 2002). The difference in the magnesium content of soils depends mainly on the richness of the magnesium in soil-forming rock. In plant tissues, magnesium is present in the form of a free or sorption bounded ion in the form of chelates, in the composition of organic compounds such as chlorophyll, phytin, pectin and an activation agent of enzymes. Magnesium binds and forms some organic and inorganic salts like oxalates, phosphates, sulfates, chlorides and more. The entry of magnesium into plants can be hindered by the acid reaction of the soil and higher amounts of sodium, potassium and aluminum ions in the soil solution. With increasing soil moisture, the ratio of monovalent and divalent ions changes in favor of monovalent ones and therefore the mobility of magnesium in the soil decreases. The main source of plant food from magnesium is the mobile part of metabolic exchange (Maguire and Cowan, 2002, Gorbanov et al., 2005). However, under certain conditions it can be toxic to plants grown on highmagnesium soils (Proctor, 1970).

Magnesium is considered to behave similarly to calcium in soils. However, a contrasting attribute between the two divalent cations in soil systems can arise from the distinct effects of magnesium on physical properties of the soils. High levels of magnesium may cause deleterious effects on soil structure similar to those caused by sodium (Oster and Jayawardane, 1998). In contrast to other cations like K, Ca, and NH_4^+ , Mg is comparatively mobile in soils. The properties or the 'behaviour' of Mg in soils can be ascribed to its unique chemical properties. Whereas the ionic radius of Mg is smaller than that of Ca, K or Na, its hydrated radius is substantially larger (Maguire and Cowan, 2002). One consequence is that magnesium is less strong bound to soil charges (CEC) leading to compared to other cations

higher Mg concentrations in the soil solution. This has consequences for the mobility of magnesium in the soil and implications for plant magnesium nutrition.

Saline soils in Bulgaria cover about 1% of the total territory. Because of their poor agricultural properties, these soils are not useful for farming, in rare cases they can be used for pastures. The most common reason for soil salinisation process is high levels of ground waters with high content of soluble salts. Such conditions are created near to the river terraces, lowlands and closed hollows, filled with fine granular sediments. These lands have poor drainage, the ground water runoff is very slow and the evaporation from the soil surface – very high. In general the territory of Bulgaria belongs to transit salt-regime zones, which is a prerequisite for developing of salinisation process.

Saline soils in Bulgaria are formed and located into two main geographical areas – Northern Bulgaria (Karaboaz lowland; Veliko Turnovo and Rousse regions; Varna region) and southern Bulgaria (Thracian lowland). Salinisation is in most cases related to intensive irrigation (secondary salinisation), but influence also have the natural hydrological factors (Dzuninski and Kavardzhiev, 1985). The land of Belozem (Plovdiv region) is one of the most representative and well researched (Buckorestliev, 1936, Vodenicharov, 1968, Dzuninski and Kavardzhiev, 1985, Penov et. al, 2011) in terms of salinity from high content of exch. Na (meadow Solonetz). They are also founded mixed saline soils (meadow Solonchak-Solonetz).

Despite the good study of the area, till yet has not been considered the question of magnesium salinity determined, although an increased content of exch. Mg has been commented in some publications. It gives grounds to make a revision of existing data and applying the already known criteria for magnesium salinity to assess the extent to which the exchange magnesium determines the overall soil salinity in Belozem.

Materials and Methods

Kavardzhiev (1986) gives a description of the land of Belozem, which occupies the second floodplain and a small part of the floodplain of the Maritza River. The low parts of the relief are mostly swamped and saline. The micro relief, the poor water permeability and the lack of vegetation in many places are the cause of severe water and wind erosion. The soil-forming materials in the plain part of the region are Pliocene sediments and quaternary materials. Pliocene deposits are high-density lake sediments composed of sandy and fine clays, clayey sands, gravels and sands in alternation to each other. The presence of montmorillonite minerals and heavy clay materials is the result of the destruction of tufogenic and marl layers. The quaternary cover is of river sediment, mainly of sandy clays and clay sands. The salinisation of soils depends mainly on the proportion of clay materials. The predominant soil type in the area of Belozem is leached cinnamon-forest soils and meadow-marsh soils. The saline leached cinnamon-forest soils are salinized mainly with chlorides and sodium sulphates. Saline meadow-marsh soils are distinguished by a greater variety of salinisation levels. The most common are slightly saline meadow sodic Solonetz, followed by Solonchak-Solonetz and Solonetz-Solonchak.

According to Penov et al. (2011) in Belozem, 40% of the land is affected by salinisation processes. Salinisation in Belozem is mainly secondary in nature. The secondary salinisation is caused by human activities such as improper irrigation, drainage and cultivation practices. There are four main soil types: Luvisols, Solonetz, Vertisols and Gleysols. Except

Solonetz, large part of Fluvisols are also strongly affected by the salinisation processes (Fig.1).

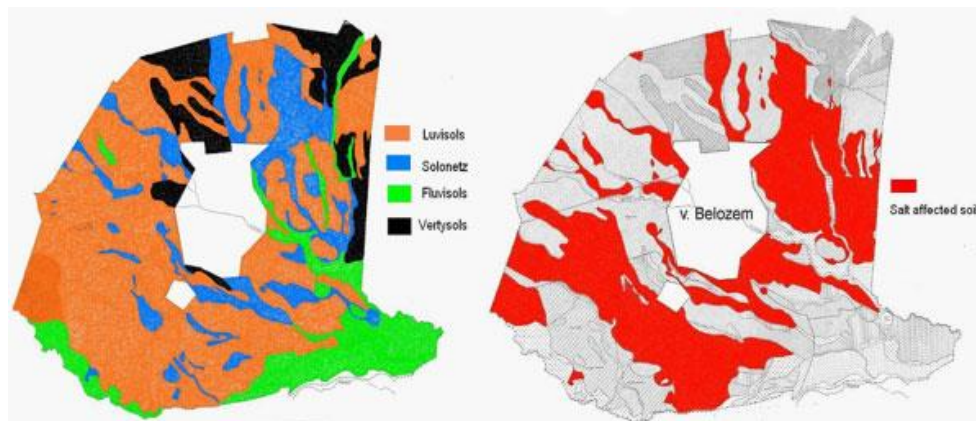


Figure 1. Soil types and saline soils in the village of Belozem (Penov et al., 2011)

For the purpose of this study, literature data from 10 representative profiles (soil analysis methods are not given) from the Belozem area were used (Pic. 1) and the existing magnesium salinity criteria were applied.

The four criteria to determine the magnesium salinity are:

- 1) Exchangeable Magnesium Percentage as “EMP” = $100 \text{ (exch. Mg/CEC)}$ more than 25% (Penkov et al. 2003, Andreeva, 2011; Qadir et al. 2018)
- 2) magnesian qualifier – $\text{exch. Ca} : \text{exch. Mg} < 1$ as “Ca:Mg” (FAO, 2015)
- 3) $100 \text{ (exch. Na + exch. Mg)/exch. Ca}$ more than >65% as “Na+Mg in % from Ca” (unpublished Kavardziev)
- 4) $100 \text{ (exch. Na + exch. Mg)/CEC}$ more than >20% as “Na+Mg in % from CEC” (Penkov, 1983).



Figure 2. Solonchak – Solonetz from Belozem region

Results and Discussion

In Table 1 are presented the basic chemical properties of the selected profiles (exchange cations, sorption capacity and pH) as they are given by their authors in the different literature sources. In Fig.1 are presented basis statistic data for those properties.

The data show that almost all profiles are well developed and reach depths of 160 cm or more. Where pH values in H₂O are given, an increase in depth is found, generally ranging from 7 to 9.9. Only in *Profile 2* (Solonetz) the pH is higher in the mid-horizons (B-horizon). Average for all ten profiles pH is 8.6 (moderately alkaline).

The cation exchange capacity (CEC) is in the wide range from < 10mequ/100g to > 45mequ/100g, which corresponds to the general characteristic of these soils (Gurov and Artinova, 2001). Predominantly the CEC for all profiles is medium to large (in the intervals 11-20 and 21-30) but in some horizons it reaches excessively large (Penkov et al., 2003). Average for all ten profiles the CEC is 25mequ/100g.

In terms of the exchange cations only potassium shows a relatively uniform distribution. The amounts of exchangeable Ca, Mg and Na vary widely, respectively for Ca from 2 to 15 mequ/100g, for Mg from 1 to 19 mequ/100g, and for Na from <0.5 to 22 mequ/100g, which leads to the vastly differences in the CEC. Average for all ten profiles exch. Ca is 6.7 mequ/100g, exch. Mg is 5.3 mequ/100g, exch. Na is 7.7 mequ/100g and exch. K is 0.5 mequ/100g. Based on the average values exch. Na is more than exch. Ca, respectively the sum of exch. Mg and exch. Na is more than exch. Ca (Fig. 3).

A correlation between the pH values and cation exchange capacity for each profile is made (Fig. 4). The results show that a good correlation between these two soil properties appear only in profile #1, #3 and #4.

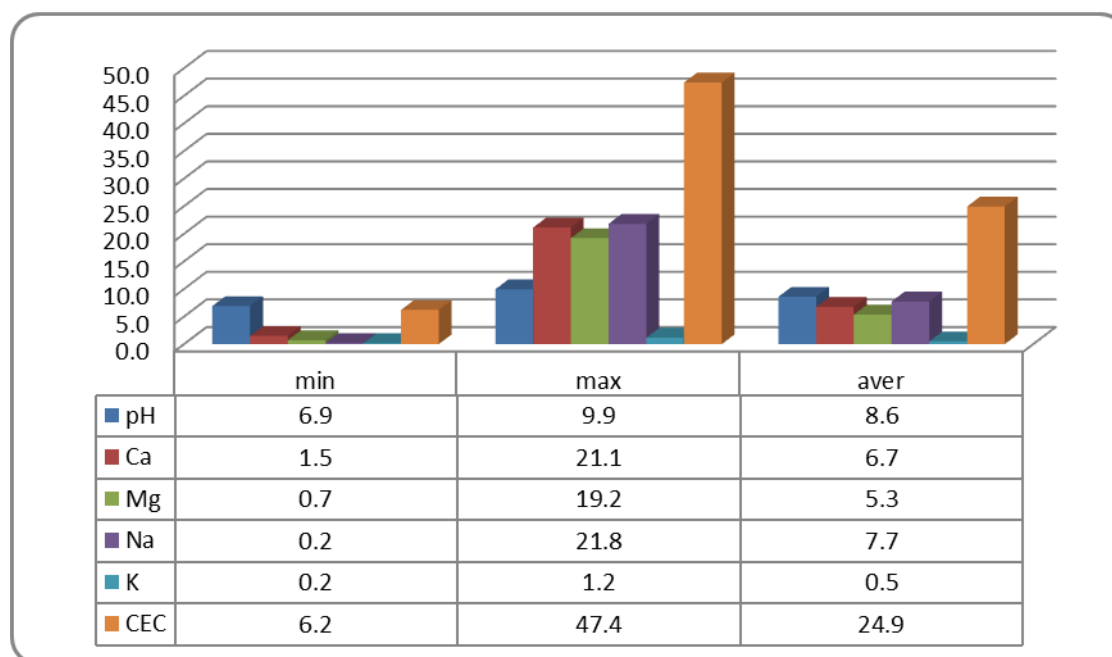


Figure 3. Minimum, maximum and average values for the basic soil properties (pH; exchangeable cations* and cation exchange capacity*) of ten soil profile from Belozem
*in mequ/100g

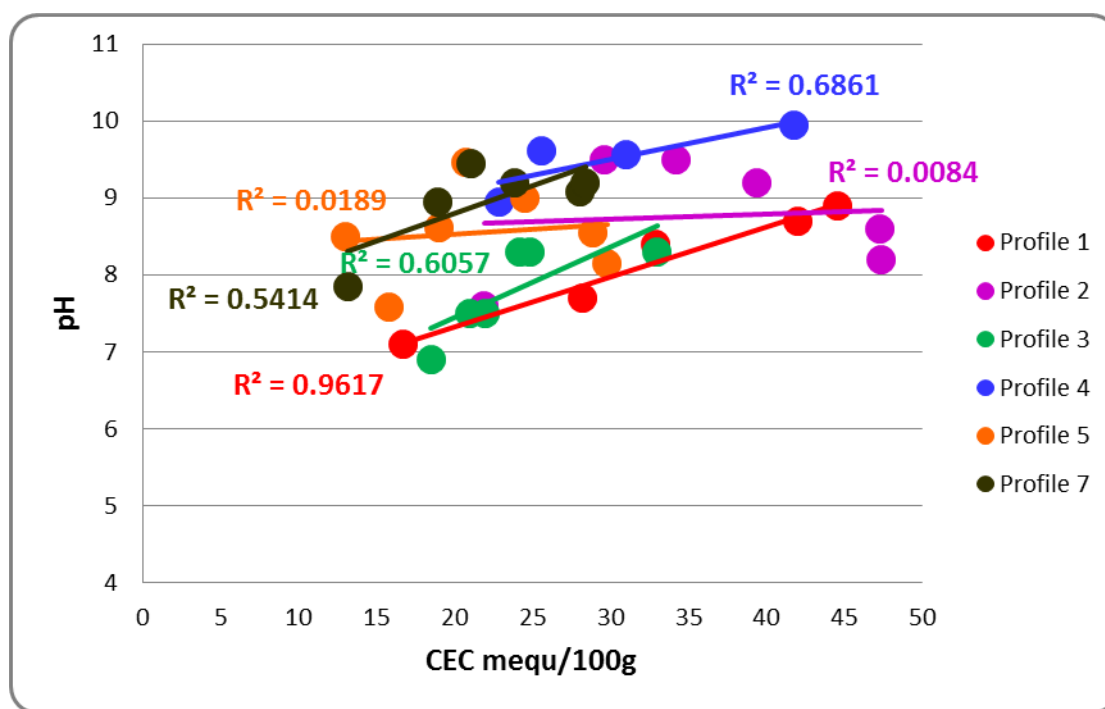


Figure 4. Correlation between pH and cation exchange capacity in six of the profiles from Belozem with R²-values

In Table 2 are presented the calculated results for the individual criteria for magnesium salinity.

Profile 1—the criteria are applied only to the first two horizons. Based on ESP, the soil is defined as Solonchak-Solonetz. However, the “EMP” is over 25% and significantly exceeds the ESP. The “Ca:Mg” ratio is about 1; “Na+Mg in % from Ca” is about 2.5 times the 65% marginal value, and “Na+Mg in % from CEC” is almost 3 times the 20% marginal value. Thus, magnesium salinity is found in these horizons according to 3 of the selected criteria, and in terms of “Ca:Mg” we can speak of a marginal case. In depth, “Ca:Mg” increases while all other indicators decrease, which is in line with the increasing content of exch. Ca.

Profile 2 – again, the criteria are applied only to the first two horizons. On the basis of ESP, the soil is defined as Solonetz. In this profile, however, the relationship between ESP and “EMP” is inversely proportional, respectively in A1, in the absence of sodium salinity (exch. Na), exch. Mg is well above 25%, while in aB exch. Na has an extremely high content (ESP 69%), which persists in B1kg and then drops sharply. The “Ca:Mg” ratio is clearly above 1; “Na+Mg in % from Ca” is near 71% and increases sharply to 495%, and “Na+Mg in % from CEC” is 2 to 4 times above 20%. So based on 3 of the criteria there is magnesium salinity in the first horizon. Taking into account the large differences in the amount of exchangeable cations, the dominant role of exch. Na in the B1kg horizon and the lack of more data, the presence of magnesium salinity cannot be uniquely determined.

Profile 3 – data is available for 4 horizons. Based on ESP, soil is defined as Meadow Solonetz. “EMP” increases in depth and exceeds ESP 2 to 3 times. “Ca:Mg” clearly decreases in depth, reaching 0.4. Respectively, “Na+Mg in % from Ca” and “Na+Mg in % from CEC” increase in depth and significantly exceed the marginal values. In this profile magnesium

salinity is found too according to 3 of the criteria and the Mg-salinity develops in depth. The “Ca:Mg” ratio is marginal.

Table 1. Basic chemical properties, exchangeable cations and cation exchange capacity of ten soil profiles from Belozem.

Atlas of soils in Bulgaria, Koynov et al., 1998 – Solonchak-Solonetz (Profile 1)											
Horizon	Depth, cm	pH in H ₂ O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-12	7.1	6.15	6.24	4.29		16.68	36.87	37.41	25.72	
B1	15-25	7.7	12.50	9.98	5.46		28.25	44.25	35.33	19.33	
B2k	30-40	8.4			3.71		32.90			11.28	
B _{Ck}	48-58	8.7			4.54		42.00			10.81	
BC _k	68-78	8.9			8.82		44.60			19.78	
C1k	110-120	8.9									
C2k	157-167	8.7									
Atlas of soils in Bulgaria, Koynov et al., 1998 – Solonetz (Profile 2)											
Horizon	Depth, cm	pH in H ₂ O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-9	7.6	12.00	8.30	0.21		21.90	54.79	37.90	0.96	
aB	18-28	9.5	4.73	2.90	20.52		29.60	15.98	9.80	69.32	
B1kg	18-28	9.5			20.98		34.20			61.35	
B2kg	44-54	9.2			10.71		39.40			27.18	
BCkg	95-105	8.6			5.11		47.30			10.80	
C1kg	137-147	8.2			2.40		47.40			5.06	
Atlas of soils in Bulgaria, Koynov et al., 1998 – Meadow Solonetz (Profile 3)											
Horizon	Depth, cm	pH in H ₂ O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-13	7.5	8.65	7.80	3.82		20.95	41.29	37.23	18.23	
AB	13-23	6.9	6.60	6.80	3.60		18.50	35.68	36.76	19.46	
B1	26-36	7.5	7.00	10.00	5.00		22.00	31.82	45.45	22.73	
B2	51-61	8.3	6.90	19.20	6.90		33.00	20.91	58.18	20.91	
BCkg	88-98	8.3			5.80		24.85			23.34	
C1kg	105-115	8.3			1.80		24.20			7.44	
C2kg	136-146	8.3									
Soil reference database in Bulgaria, Teoharov et al., 2009 – Solonetz (Profile 4)											
Horizon	Depth, cm	pH in H ₂ O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-30	8.9	13.98	4.62	1.36	0.41	22.83	61.24	20.24	5.96	1.80
B1	30-60	9.6	8.88	8.10	7.69	0.50	30.98	28.66	26.15	24.82	1.61
B2C1	60-115	9.6	4.01	10.29	9.72	0.52	25.54	15.70	40.29	38.06	2.04
C2	115-160	9.9	2.56	8.12	5.00	0.25	41.74	6.13	19.45	11.98	0.60
Soil reference database in Bulgaria, Teoharov et al., 2009 – Solonchaks-solonetzsalic-sodic (Profile 5)											
Horizon	Depth, cm	pH in H ₂ O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-3	7.6	9.10	2.52	0.45	0.74	15.80	57.59	15.95	2.85	4.68
A2	3-7	8.5	5.77	2.07	1.14	0.40	13.00	44.38	15.92	8.77	3.08
B1	7-15	8.6	4.26	4.75	5.24	0.47	19.00	22.42	25.00	27.58	2.47
B2	15-36	8.2	15.00	7.48	6.25	0.53	29.80	50.34	25.10	20.97	1.78
B3	36-70	8.6	12.52	8.76	10.22	0.54	28.90	43.32	30.31	35.36	1.87
B4C1	70-125	9.0	1.80	12.99	9.13	0.47	24.50	7.35	53.02	37.27	1.92
C2	125-170	9.5	5.16	10.00	5.15	0.31	20.70	24.93	48.31	24.88	1.50

Table 1. Basic chemical properties, exchangeable cations and cation exchange capacity of ten soil profiles from Belozem – (Continue)

Penkov et al., 1985 – Meadow Solonetz (sodic) (Profile 6)											
Horizon	Depth, cm	pH in H ₂ O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-4		1.48	0.72	3.06	0.18	8.12	18.23	8.87	37.68	2.22
B1	4-12		4.40	1.78	9.12	0.26	16.86	26.10	10.56	54.09	1.54
B2	12-32		5.36	1.83	11.15	0.26	19.15	27.99	9.56	58.22	1.36
B3	32-60		5.82	1.64	13.05	0.41	22.72	25.62	7.22	57.44	1.80
B4C1	60-125		4.18	1.46	10.82	0.36	18.18	22.99	8.03	59.52	1.98
C2	125-165		5.92	1.15	4.18	0.32	15.25	38.82	7.54	27.41	2.10
Penkov et al., 1985 – Meadow Solonchak-Solonetz (sodic-sulfatic) (Profile 7)											
Horizon	Depth, cm	pH in H ₂ O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-3	7.85	3.35	1.69	4.56	0.92	13.15	25.48	12.85	34.68	7.00
A2	3-12	8.95	3.26	2.13	10.15	1.05	18.93	17.22	11.25	53.62	5.55
B1	12-36	9.08	3.68	4.10	12.35	1.16	28.02	13.13	14.63	44.08	4.14
B2	36-38	9.20	4.32	3.98	12.48	1.05	28.38	15.22	14.02	43.97	3.70
B3C1	68-120	9.20	4.86	2.92	13.52	0.69	23.82	20.40	12.26	56.76	2.90
C2	120-165	9.45	3.74	3.18	8.16	0.61	21.06	17.76	15.10	38.75	2.90
Penkov, 1995 – Solonchak-Solonetz (Profile 8)											
Horizon	Depth, cm	pH in H ₂ O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	N	K
Als	0-15		1.80	0.80	3.40	0.20	6.20	29.03	12.90	54.84	3.23
B1tsl	15-40		7.20	2.60	18.50	0.40	28.70	25.09	9.06	64.46	1.39
B2tsl	40-80		8.20	1.90	21.50	0.40	32.00	25.63	5.94	67.19	1.25
B3tsl	80-120		8.60	1.60	21.80	0.40	32.40	26.54	4.94	67.28	1.23
Ck	120-160		7.00	1.80	18.20	0.30	27.30	25.64	6.59	66.67	1.10
Vodenicharov, 1968 – Section 13 (Profile 9)											
Horizon	Depth, cm	pH in H ₂ O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
	0-15		9.48	3.45	2.17		15.10	62.78	22.85	14.37	
	15-25		16.06	4.57	1.91		22.54	71.25	20.28	8.47	
	25-35		21.11	5.51	2.70		29.32	72.00	18.79	9.21	
Vodenicharov, 1968 – Section 15 (Profile 10)											
Horizon	Depth, cm	pH in H ₂ O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
	0-1		6.66	2.46	3.52		12.64	52.69	19.46	27.85	
	1-8		2.73	4.42	3.70		10.85	25.16	40.74	34.10	
	8-17		2.37	9.89	7.22		19.48	12.17	50.77	37.06	
	23-42		3.33	13.31	9.57		26.21	12.71	50.78	36.51	
	42-70		5.75								
	70-80		4.79								

Table 2. Calculated criteria for magnesium salinity applied to each soil horizon

Profile 1		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
Ah	0-12	37.41	25.72	1.0	171.2	63
B1	15-25	35.33	19.33	1.3	123.5	55
B2k	30-40		11.28			
BCk	48-58		10.81			
BCk	68-78		19.78			
Profile 2		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
Ah	0-9	37.90	0.96	1.4	70.9	39
aB	18-28	9.80	69.32	1.6	495.1	79
B1kg	18-28		61.35			
B2kg	44-54		27.18			
BCkg	95-105		10.80			
C1kg	137-147		5.06			
Profile 3		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
Ah	0-13	37.23	18.23	1.1	134.3	55
AB	13-23	36.76	19.46	1.0	157.6	56
B1	26-36	45.45	22.73	0.7	214.3	68
B2	51-61	58.18	20.91	0.4	378.3	79
BCkg	88-98		23.34			
C1kg	105-115		7.44			
Profile 4		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
A1	0-30	20.24	5.96	3.0	42.8	26
B1	30-60	26.15	24.82	1.1	177.8	51
B2C1	60-115	40.29	38.06	0.4	499.0	78
C2	115-160	19.45	11.98	0.3	512.5	31
Profile 5		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
A1	0-3	15.95	2.85	3.6	32.6	19
A2	3-7	15.92	8.77	2.8	55.6	25
B1	7-15	25.00	27.58	0.9	234.5	53
B2	15-36	25.10	20.97	2.0	91.5	46
B3	36-70	30.31	35.36	1.4	151.6	66
B4C1	70-125	53.02	37.27	0.1	1228.9	90
C2	125-170	48.31	24.88	0.5	293.6	73
Profile 6		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
A1	0-4	8.87	37.68	2.1	255.4	47
B1	4-12	10.56	54.09	2.5	247.7	65
B2	12-32	9.56	58.22	2.9	242.2	68
B3	32-60	7.22	57.44	3.5	252.4	65
B4C1	60-125	8.03	59.52	2.9	293.8	68
C2	125-165	7.54	27.41	5.1	90.0	35
Profile 7		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
A1	0-3	12.85	34.68	2.0	186.6	48
A2	3-12	11.25	53.62	1.5	376.7	65
B1	12-36	14.63	44.08	0.9	447.0	59
B2	36-38	14.02	43.97	1.1	381.0	58
B3C1	68-120	12.26	56.76	1.7	338.3	69
C2	120-165	15.10	38.75	1.2	303.2	54

Table 2. *Calculated criteria for magnesium salinity applied to each soil horizon – (Continue)*

Profile 8		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
Als	0-15	12.90	54.84	2.3	233.3	68
B1tsl	15-40	9.06	64.46	2.8	293.1	74
B2tsl	40-80	5.94	67.19	4.3	285.4	73
B3tsl	80-120	4.94	67.28	5.4	272.1	72
Ck	120-160	6.59	66.67	3.9	285.7	73
Profile 9		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
	0-15	22.85	14.37	2.7	59.3	37
	15-25	20.28	8.47	3.5	40.3	29
	25-35	18.79	9.21	3.8	38.9	28
Profile 10		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
	0-1	19.46	27.85	2.7	89.8	47
	1-8	40.74	34.10	0.6	297.4	75
	8-17	50.77	37.06	0.2	721.9	88
	23-42	50.78	36.51	0.3	687.1	87

Profile 4 – soil is defined as Solonetz. Accumulation of exch. Na is distinct in the B-horizon, where exch. Mg is accumulated. The criteria for ESP and “EMP” are approximately equal, with a slight preponderance of “EMP”. Due to the heterogeneous content of all exchangeable cations in different horizons, the magnesium salinity indexes also vary considerably. Thus, only in B2C1 is clear indication of magnesium salinity, but in this horizon ESP is also crucial for overall salinisation. Therefore, in this profile magnesium salinity can only be mentioned in the B2C1 horizon.

Profile 5 – the soil is defined as Solonchaks-solonetz, salic-sodic. The data for the entire profile, made up of 7 horizons, is available. In depth, “EMP” increases, with B1 downwards exceeding 25%, and in the lower horizons exceeding ESP values. The “Ca:Mg” ratio is below 1 in B1 and the lowest two horizons. In the other horizons it is well above 1. The “Na+Mg in % from Ca” and “Na+Mg in % from CEC” criteria are below their marginal values in the surface horizons and then increase sharply. The mixed salinisation plays a decisive role in the redistribution of the cations in the individual horizons, with the more mobile Na and Mg being removed from the surface horizons, but in depth they accumulate in sufficient quantities for the manifestation of both strong Na and Mg salinity.

Profile 6 — in this profile, defined as Meadow Solonetz (sodic), the content of exch. Mg is low; respectively “EMP” barely reaches values of more than 10%. The “Ca:Mg” ratio is well above 1. The “Na+Mg in % from Ca” and “Na+Mg in % from CEC” criteria show magnesium salinity, but take into account the high content of exch. Na those criteria cannot be taken as unambiguous indicators. Thus, in this profile the magnesium salinity cannot be determined.

Profile 7 – here the “EMP” is below 25% too (from 11 to 15%). The “Ca:Mg” ratio ranges from 0.9 to 2.0 in different horizons. The “Na+Mg in % from Ca” and “Na+Mg in % from CEC” are again extremely high due to the high content of exch. Na. Again, magnesium salinity cannot be clearly determined.

Profile 8 – the results for this soil are similar to those of profile 6 and no magnesium salinity is determined.

Profile 9 – this soil is given as an example of Solonetz, but all indicators show a lack of salinity from exchangeable Na and Mg cations. Only by “Na+Mg in % from CEC” the values are above the 20% margin, but all others are below their margins.

Profile 10 – immediately impresses the higher values for “EMP” and ESP, as EMP is more than ESP. With the exception of the surface horizon, the depth “Ca:Mg” sharply and significantly decreases below 1. The “Na+Mg in % from Ca” and “Na+Mg in % from CEC” are extremely high. Thus, this soil is with well-expressed magnesium salinity.

Conclusions

From the analysis of the available literature data for 10 soil profiles from the land of Belozem, the following conclusions are done:

1. In three of the profiles (#1, #3, #10) it can be clearly stated that there is an increased content of exchanged Mg and this lead to manifestation of magnesium salinity respectively. At least the values of 3 criteria are fulfilled and the fourth is marginal.

2. In four of the profiles (#6, #7, #8, #9) the content of the exchangeable Mg doesn't reach levels to indicate magnesium salinity. The “EMP” is low, below 20% even less than 10%, “Ca:Mg” is more than 2 (by marginal value less than 1), and in *Profile 9* even one of the criteria, which assume the exchangeable Na, is also below its marginal value.

3. In three of the profiles (#2, #4, #5), the magnesium salinity is found unevenly in different horizons.

4. Considering the existing magnesium salinity criteria, it is recommended to use all of them in combination, since the use of only one of them can lead to misleading conclusions, especially in combination with high values of exchangeable Na.

5. The examined profiles revealed that there are horizons in which EMP is crucial for salinisation ($ESP < 20\%$), as well as whole profiles in which EMP exceeds ESP at $ESP > 25\%$. This should be taken into account when interpreting the criteria for magnesium salinity.

The obtained results can serve as a new classification definition of the selected soil profiles (adding a magnesium index for the designation of diagnostic horizons, as well as marking magnesium in the main name), further evaluating the role of the exchangeable magnesium for their physical and chemical properties and their structural properties and to look for new concepts for the reclamation of these soils in view of the high content of exchangeable magnesium.

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Test of the Biological Module of CERES-Maize Model in Lysimeters on Chromic Luvisols

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Abstract

This paper reports on CERES-maize model stepwise calibration, modification and validation using independent data from specific experiments carried out in a chromic luvisol (Chelopechene), Sofia field, 1997-1999. Laboratory based water conductivity curve WCC (eq.1) and water retention curve WRC (eq.2) are calibrated (step i) and adjusted to data measured in field (step ii) (Fig.1; Table 3). Field observations of water dynamics under maize hybrid Kn 509 relative to optimal nitrogen supply N200 (kg ha⁻¹) and variable water stress (irrigated A1 plots/lysimeters №1 and №2) are used to modify the function of Root Water Absorption (eq.3) (step iii). The ability of calibrated biological module of CERES-NC-Maize model to make predictions without any further adjustments of parameters is tested against independent three-year dataset (1997-1999) collected in the same field (Chelopechene) but in lysimeter №1 (step iv). Observed water contents in the 1.30 m root zone PESW and soil layers SW (Figs.3a, 3b, 3c, 3d), actual crop water uptake (evapotranspiration ET) (Figs. 4 and 5) and water fluxes prove acceptable agreement with validated model outputs. Model predictions of crop growth and dry weights of maize are acceptably precise in most of the tested situations (Fig.6). The results support the use of tested CERES-NC model in prediction of aboveground dry matter, water balance and storage under maize on Chromic Luvisols in Sofia field.

Key words: “crop-soil-atmosphere” system, transport of water, lysimeters’ experiments; CERES-NC-maize model parameterisation, model predictive capacity

Introduction

Evaluation of environmental impacts and consequences of hydrological events requires estimation of different fluxes of water and pollutants, associated with agricultural practice and pedoclimate data, within the “soil-plant” system and at its boundaries. Such variables, as crop evapotranspiration, fluxes of water and nitrogen below the root zone, yield etc, are estimated by balance of water and nitrogen in the system. Model use in a predictive mode is indispensable in such analyses. Numerous models, dealing with the risk of pollution and consequences of hydrological extremes in agriculture, have been developed for the last twenty years. They treat the ensemble of processes in the cycle of water and nitrogen of the

soil-crop system. In the general structure of such models three basic modules usually describe the following phenomena:

-physique: transport of water, solutes etc. in the soil and its interface with the atmosphere,

-microbiological: degradation of the organic matter in the soil, nitrification, denitrification,

-biological: growth and development of plants related to their functioning in the soil by the module of root uptake.

Different level of details is possible in each module. Predictive capacity and parameterisation feasibility of the modified CERES-maize model (Jones & Kiniry 1986; Gabrielle et al.1995; Gabrielle et al.1996) have been tested with Bulgarian pedoclimate and crop data within the framework of an INCO-COPERNICUS project (Forth framework Program of EC) on evaluation of risks and monitoring nitrogen and pesticides fluxes at the crop level on the Romanian and Bulgarian plain. Soil and crop model parameters were calibrated on a Chromic Luvisol (Chelopechene field, Sofia region) on the basis of data collected under optimal nitrogen dressing from dry lands, optimally irrigated plots and lysimeter №2 in 1997 (Final Project Report of IC15CT96-0101; Popova et al., 1999; Popova and Kercheva, 2005). Modelling the dynamic of water and nitrogen uptake by plant plays a critical role since it intervenes in the principle terms of water and nitrogen balance in the soil-crop system. The objective of this report was to improve and validate CERES-maize model predictions about water disposal in the soil and biological response to it for the situation under study. For that purpose the functions of root water absorption-RWA and crop growth (Jones & Kiniry 1986) were tuned under maize. Validation data were collected from similar situations in the same field but in a different lysimeter (№1) in 1997 and following 1998 and 1999. The biological module was validated over three years by comparing the model output to observed lysimeter data, which were not used in model calibration so far, as crop evapotranspiration, soil water disposal and dry matter content in above ground plant and ears.

Materials and Methods

Environment of models' test

Modified CERES-maize model (Jones & Kiniry 1986; Gabrielle et al.1995; Gabrielle et al.1996) was tested at the experimental site of Chelopechene in the region of Sofia. The soil is a moderately permeable Chromic Luvisol (Table 1).

The region of Sofia belongs to the European moderate-continental zone. Mean air temperature in the coldest month January is -2.4°C , and it is 20.2°C in the hottest one July. Annual precipitation sum is 636 mm on the average. The precipitation totals during maize vegetation periods-Pr (Table 2) are not enough to satisfy potential crop water use and in most of the years irrigation requirements (I) vary from 60 to 276mm.

Table 1. Soil texture and laboratory based saturated hydraulic conductivity ($K_{sat-lab}$), Chelopechene field.

Depth, cm	Soil texture classification	Soil particles, %			$K_{sat-lab}$ cm/day
		Clay <0,002 mm	Silt 0,002- 0,05 mm	Sand 0,05-2,00 mm	
0-28	clay loam	32	32	36	93,30
33-45	clay	43	27	30	15,90
61-71	clay	42	25	33	20,20
95-130	Sandy clay loam	24	15	61	39.90

Vegetation seasons of model test (1997, 1998 and 1999) covered a wide range of input water balance components- I and Pr (table2) and probability of exceedance of precipitation P ($28\% < P < 67\%$).

Table 2. Precipitation totals (Pr, mm), probability of exceedance of precipitation (P, %) and irrigation depths (I, mm) in Chelopechene field during different maize vegetation periods.

Vegetation Period	Years of extremes				Years of model test					
	P=10% (Wet)		P=90% (Dry)		1998,P=59% (Average)		1997, P=67% (Moderately dry)		1999,P=28% (Moderately wet)	
	Pr, mm	I, mm	Pr, mm	I, mm	Pr, mm	I, mm	Pr, mm	I, mm	Pr, mm	I, mm
1.05-30.09	380	61 ¹	180	276 ¹	277	160 ¹	263	183 ¹ 132 ²	349	160 ¹ 120 ²

¹) Required irrigation depths for water application scheduled at 85% of FC (according CROPWAT programme, Smith, 1991)

²) Real irrigation depths in lysimeter №1.

Three-year meteorological data (air temperature, precipitation, wind velocity, air humidity and global sun radiation) monitored on a daily basis in MTO field station of N. Poushkarov Institute of Soil Science (1997-1999) were used in these analyses.

Descriptions of the model and its modifications

CERES model (Jones & Kiniry 1986) is composed of different sub-models, each one functioning independently with its own input/output, and using atmosphere/plant/soil parameters. Redistribution of precipitation/irrigation input, values of drainage, potential evapotranspiration, actual soil evaporation and plant transpiration are calculated in the soil water balance subroutine. Following an infiltration a layer can hold the amount of water corresponding to the difference between current volumetric water content and saturation (SAT). If the new soil water storage is more than Drain Upper Limit (**DUL**) the excess of water above DUL drains by unsaturated flow from the layer and the potential infiltration in the next layer is set. The total flow out of the lowest layer of the soil profile presents deep percolation. Water Flow Sub-model is taken from Gabrielle et al. (1995) who has

implemented a semi-empirical Darcy's law for water movement in the soil profile in saturated and unsaturated conditions. He uses the following equations of **WCC** (water conductivity curve):

$$K(\theta) = K_{\text{sat}} \cdot \exp [A(\theta - \theta_{\text{sat}})] \quad (1)$$

and water retention curve –**WRC** (Driessen, 1986):

$$\phi(\Theta) = \exp \sqrt{\frac{\log \frac{\Theta_{\text{sat}}}{\Theta}}{\gamma}} \quad (2)$$

, where $K(\theta)$ and K_{sat} (cm day^{-1}) are the hydraulic conductivity respectively at θ and θ_{sat} water contents, θ_{sat} ($\text{cm}^3 \text{ cm}^{-3}$) is volumetric water content at saturation, parameter A (unitless) depends on soil texture and hydrologic classes, $\phi(\theta)$ (cm water) is the matrix suction, parameter γ (cm^{-2}) is a texture related constant that accounts for the soil suction curve. Soil water balance subroutine also calculates potential and actual evaporation and transpiration by the model of Ritchie (1972). Upward and downward unsaturated flows between the Lower Limit (LL) and DUL are thus calculated (Jones & Kiniry 1986). In the model (Jones & Kiniry 1986) the process of crop uptake in the soil is interpreted in terms of crop demands and soil disposal. The flux of root water absorption J_w ($\text{m water day}^{-1} \text{m}^{-1} \text{ root}$) is calculated for a layer of soil of thickness Z (m) by the following equation:

$$J_w = 2.67 \cdot 10^{-5} \frac{\exp[62(\theta - \theta_{pf})]}{6.68 - \ln(RLV)} Z \quad (3)$$

, where θ is average volumetric water content in the day, θ_{pf} is wilting point. RLV is root length density ($\text{m root m}^{-3} \text{ soil}$). This function reflects the disposition of water in the soil as well as the capacity of the root system to extract its elements. The crop model of CERES-maize is consisted of three modules of crop growth: phenological one, module of photosynthesis and module of restraints. The last one confronts the demands of the plants with the soil disposal and then penalises the functions of crop growth and elongation under limiting conditions.

CERES-maize model (Jones & Kiniry 1986; Gabrielle et al. 1995) was purposely modified in this study. The simulation of preferential fluxes and thus soil nitrogen fate was improved by introduction of special looping in the model code which redistributed immediately the excess of input water above SAT in the top soil layer by saturating consistently the lower layers in the manner of cascade.

Model calibration and validation specifics

Model test on a Chromic Luvisol has been in process since 1997 according to the following methodology: (i) deriving a first set of soil and crop development model parameters for the water balance sub-model; (ii) adjustment of laboratory WRC (eq.2) to water retention data measured in field; (iii) using these optimised parameters for calibrating the remaining biological parameters of crop growth and root water absorption (RWA-eq.3); and (iv) adjustment of soil and crop parameters for variable nitrogen treatments. Field data obtained from the experiments with optimal nitrogen dressing and variable water stress were used for steps (i), (ii) and (iii). These steps were initially made of data collected from dry lands, optimally irrigated plots and lysimeter №2 in 1997, when maize vegetation season was moderately dry (Final Project Report of IC15CT96-0101; Popova, 2008; Popova et al., 1999,

Popova 2000). The calibration of water balance sub-model (step i and step ii) used to be performed on a part of the data set (from irrigated and non-irrigated plots) while the other part from lysimeter №2 (the “split sample method”) were used to validate step (i) and step (ii) and then to start calibration step (iii) by testing and modifying, if needed, the functions of RWA (eq.3) and crop growth. Model modification in order to predict better preferential fluxes and redistribution of precipitation and irrigation water input in the soil was also checked. The ability of calibrated and modified model to make predictions without any further adjustments of parameters was tested in this study against independent three-year data (1997, 1998, 1999) collected in the same field but from lysimeter №1 during project and post-project field campaign (extrapolation test). These data were not used in the calibration exercise so far. Soil moisture for model validation was assessed by tensiometers (Hillel, 1980) and TDR (Guidelines for TRIME application, Fundinger et al., 1995). For this purposes the lysimeter №1 was instrumented with mercury tensiometers at the depth 40, 70, 100 and 130cm (since June 1997) and fibber-glass probe access tubes installed till 2m (since 1998). Data about actual maize evapotranspiration-ET in the lysimeter were obtained by water balance and justified with independent ET calculations (Delibaltov, 1972; Zahariev et al.1986) in a companion paper presented in a conference. Model input of reference surface evaporation for the years of model test was calculated for alfalfa on the bases of daily climate records. Dry weights of the crop components were evaluated by destructive sampling of 2-4 plants over vegetation and 70-100 plants at harvest. All these data were extensively used for validation by comparing them to model output. Such procedure was adopted to make sure that finally the parameters of physical water transport in the soil and at the boundaries of the soil-crop system and biological extraction of the roots were representative for the field. The goodness of model predictions was evaluated by graphical methods. Graphical model test included comparison between simulated and measured soil moisture content and potentially extractable soil water-PESW in the root zone, maize evapotranspiration and dry matter weights of above ground crop and ears (grains +cobs + leaf sheets) in one and the same lysimeter №1 over the period from 1.05.1997 to 1.10.1999.

Results and Discussion

Results were presented following the stepwise procedure of CERES-maize model test
Improvements of predictions of water disposal in the soil

Water retention curve (eq.2) of CERES-maize was fit to laboratory based data (Koleva, 1973 ; Kalcheva 1991) in calibration step (i) as shown in Fig.1-a and then adjusted in Fig 1-b to field tensiometers reading (step ii). As a result of calibration step (ii) θ_{sat} (eq.2) was adjusted to field conditions by regressing tensiometers' data points under the constraint to keep γ -slope parameter at the laboratory-based value (dashed line in Fig.1-b). Step (ii) proved that “laboratory WRC“(full line in Fig.1-b) overestimated water content by 0.07-0.12 cm³/cm³ on the Chromic Luvisol. Soil water parameters derived after step (i) and step (ii) of model calibration were listed in Table 3.

CERES-maize (Jones & Kiniry 1986; Gabrielle et al.1995) calibration exercises on multilayered Chromic Luvisol (table 1) showed that after intensive water supply, due to the daily step of model simulations, the withdrawal of the excess of water above field capacity

from the top layer took much more time (several days) then the real water redistribution time in reality (Fig.2).

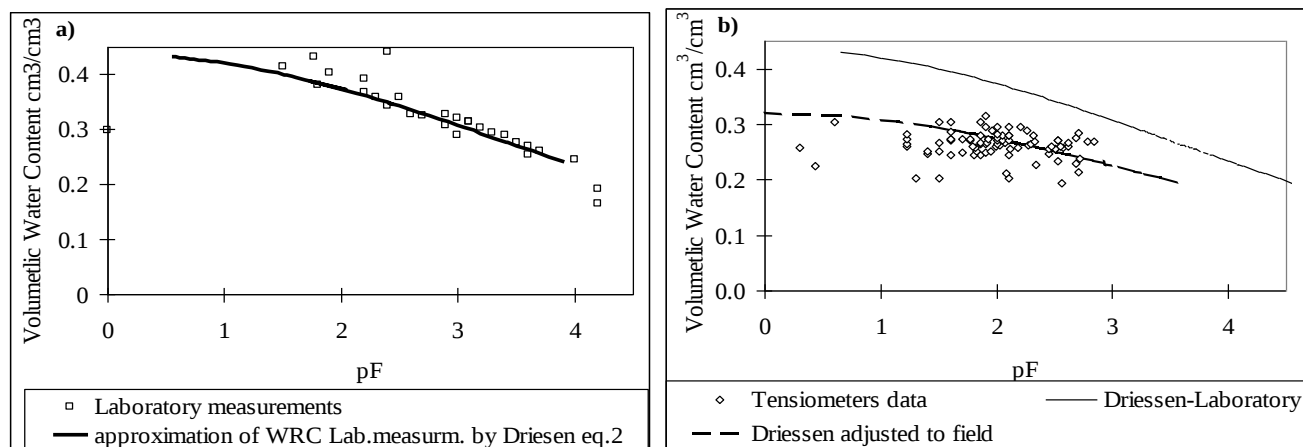


Figure 1. Calibration of WRC (eq.2) for the clay layer (33-70 cm) in Chelopechene site: **a)** Derivation of parameters from laboratory measurements (step i); **b)** adjustment of eq.2 to field tensiometers readings in 1995/96/97 (step ii).

Table 3. Parameters of WRC (Eq.2) and WCC (Eq.1) after calibration step (i) and step (ii) in Chelopechene.

Parameter	A-Eq.1	θ_{sat} (Eq.1 and 2)		γ (Eq.2)
Method		Laboratory Step (i)	Field Step (ii)	Laboratory and field Step (i) and step (ii)
	-	cm ³ /cm ³	cm ³ /cm ³	cm ⁻²
A-horizon	199.0	0.440	0.370	0.0124
B-horizon	150.0	0.437	0.318	0.0074

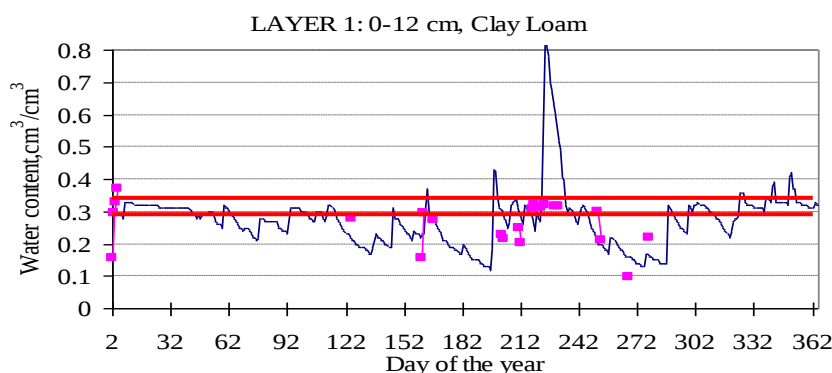


Figure 2. Measured and simulated (before introduction of preferential flow looping in the model code) water contents for the top soil layer (0-12cm) in Chelopechene (1.Jan.-31.Dec.1997). Two horizontal thick lines represent field capacity and saturation of the layer.

Introduction of preferential flux looping in the modified version used in this study improved model predictions of soil water in the top layer (Fig.3-b) by redistributing immediately the excess of water above saturation there in the deeper layers (Fig.3-c and Fig.3-d).

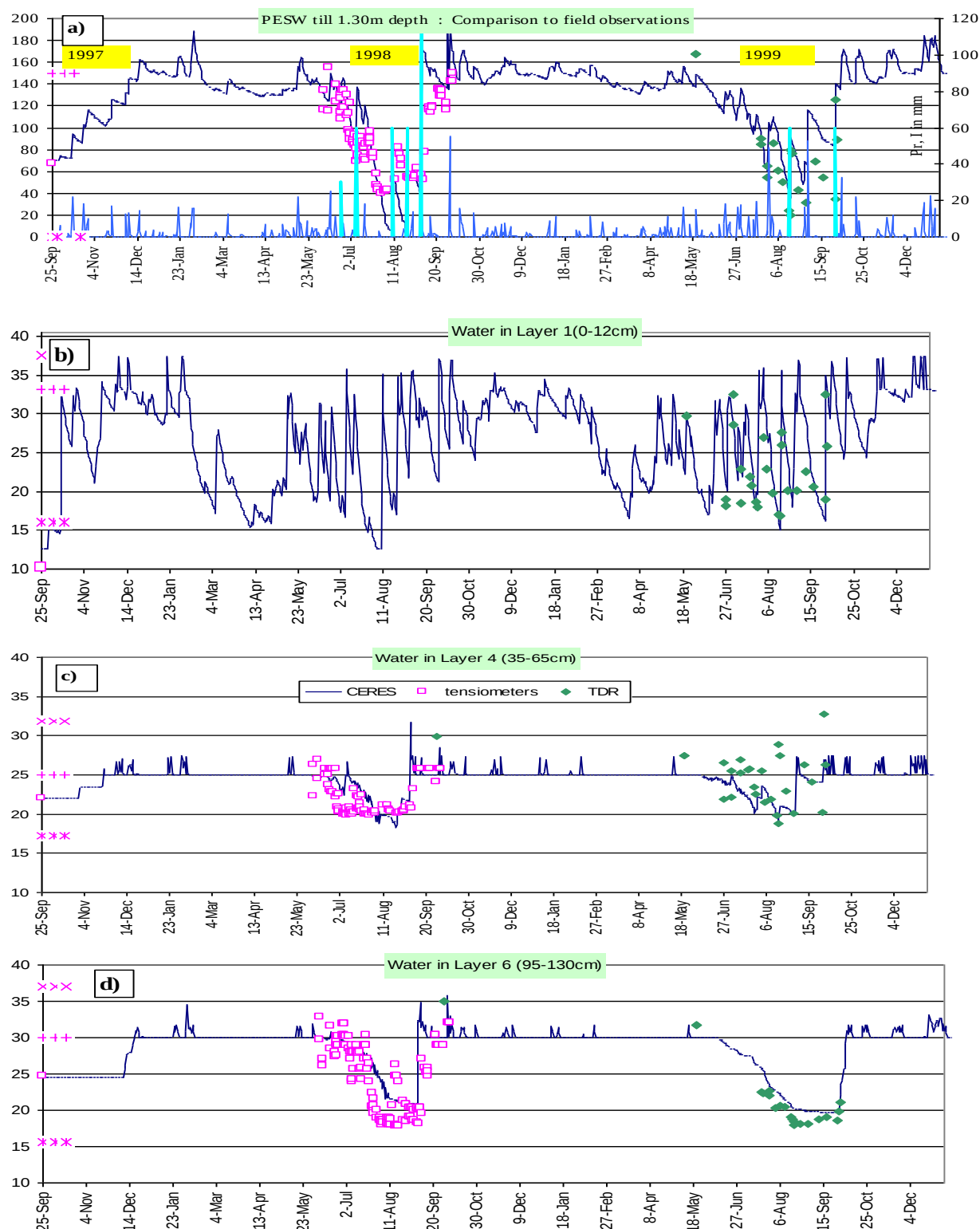


Figure 3. Comparison between observed and predicted (after calibration) PESW(mm) and soil moisture content SW(% v/v) under maize in Chelopechene (25.Sept.1997-1.Oct.1999) in soil layers 0-12, 35-65, 95-130cm. Symbols correspond to PESW/SW at: ***-WP, +++ FC, xxx-saturation of soil layers.

Using optimized parameters after calibration, the model was run from 25.09.1997, starting on specified initial soil water content values, till 6.10.1999 (Fig.3). The agreement

between model simulation lines of potentially extractable soil water in 1.30m-root zone (PESW) in Fig.3-a and soil water content in different genetic layers (Fig.3-b,-c,-d) on the one hand and field observations (presented in symbols) over two consequent full “fallow state vegetation” cycles showed the acceptability and accuracy of optimized parameter set. Figure 3 proved the overall ability of modified and calibrated soil water balance subroutine of CERES-maize model to predict the redistribution of water input, as precipitation and irrigation, in the soil layers and thus water disposal for crop growth without any further adjustments of the model parameters.

Improvements of model biological prediction

Functions of root water absorption-RWA (eq.3) and crop growth were tuned to lysimeter observations of evapotranspiration and dry weights in calibration step (iii). The initial calibration test against biological data from lysimeter №2, 1997 showed that, nevertheless that soil water physical transport was correctly simulated, model predictions were not correct. RWA function (eq.3) was adjusted to the local higher capacity of the root system to extract water by modification of the power 5 (eq.3) to 3. The latter change in the model code resulted in acceptable agreement between model output and observed evapotranspiration (lysimeters № 1 and № 2 in Fig.4.) and crop dry weights in 1997. It should be noticed that measuring equipment, water balance and dry weights estimates in both lysimeters are completely independent.

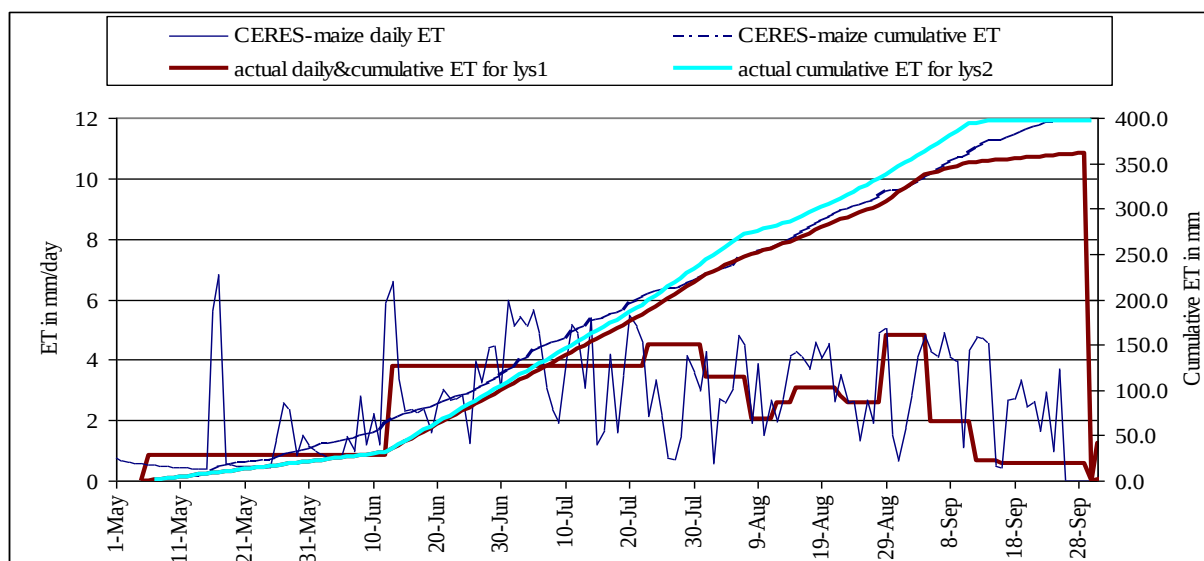


Figure 4. Comparison between predicted ET (after adjustment of eq.3) and actual ET from water balance data, lysimeter №1 and lysimeter №2, Chelopechene 1997.

Calibrated biological functions were validated then for a similar situation for the next years (1998 and 1999). Overall graphical model test against three-year independent lysimeter data was illustrated towards water uptake in Fig.5 and dry weights of crop in Fig.6. Actual crop evapotranspiration, as obtained from lysimeter observations, was plotted in stepped thick line for the daily rates (Fig.5) and in symbols for cumulative terms. Actual ET (thick lines in the Fig. 5) was compared with corresponding simulated one after RWA (eq.3) calibration (fine lines).

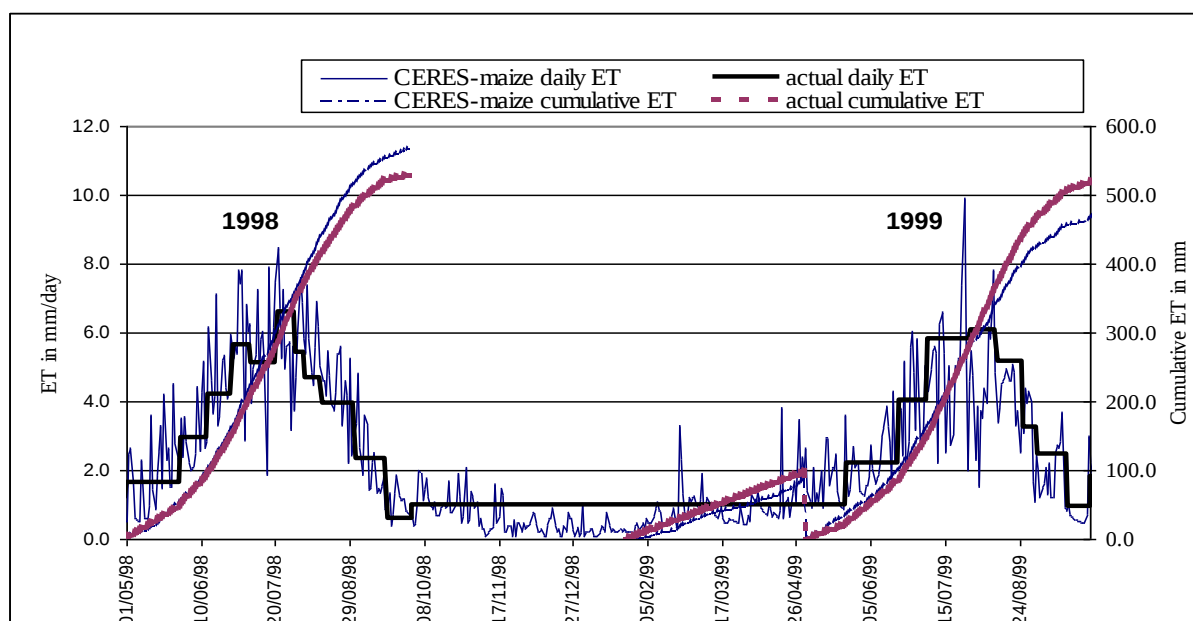


Figure 5. Validation of modified root water absorption function (eq.3) by comparing predicted to observed evapotranspiration (1.May.1998-1.Oct.1999) in lysimeter №1 Chelopechene.

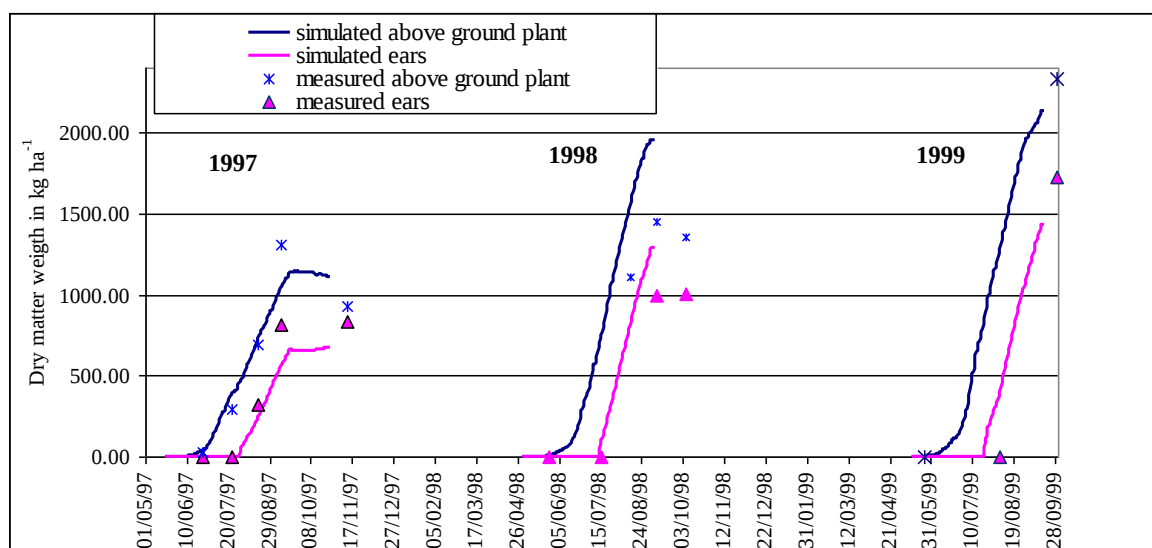


Figure 6. Validation of crop growth functions by comparing predicted to observed dry weights of maize (1.May.1997-1.Oct.1999) in lysimeter №1 Chelopechene.

Experimentally obtained dry weights of the crop partitioned to ears and total above ground plant were presented in symbols in Fig.6 while lines were validated model simulations. The agreement between observed and predicted maize evapotranspiration and dry weights (from 1.May 1997 till 1.Oct.1999) was acceptable. Since the vegetation period in 1997 (140 days) was shorter than the following ones in 1998(160 days) and 1999(156 days), cumulative maize evapotranspiration was 362 mm in 1997, 528 mm in 1998 and 518mm in 1999. This difference was mainly due to the later planting date in 1997. Model capability to predict evaporation from bare soil was proved by comparison of observed and predicted cumulative ET in fallow state (from 20.01. to 1.05.1999).

Conclusion

The use of the procedure of stepwise calibration and validation, consisting of comparing model output to observed three-season biological data from lysimeters, enabled to improve the prediction capacity of modified CERES-NC-maize model under Bulgarian conditions. Overall model performance evaluation was provided by graphical methods applied in all steps of model test. The stepwise calibration procedure, starting with transport of water, followed by crop growth and root water absorption, improved parameters' set and biological predictions for the situation under study. As a result of model code modifications and adopted calibration methodology simulation output proved to be accurate enough over a comparatively long period (1.05.1997-1.10.1999). Model simulated acceptably water transport, including preferential fluxes, maize evapotranspiration, evaporation from bare soil and dry weights. The modifications of the modules of soil water and crop growth and derived input parameter set of CERES-maize model would make more plausible risk assessment of environmental impacts and consequences of drought under maize in studied pedoclimate combination.

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Effects of Organic Matter and Live Plants on Sulfidic Soil pH, Redox and Sulfate Content under Flooded Conditions

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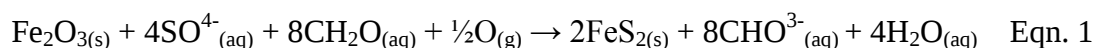
Abstract

In an undisturbed state below the water table, the sulfidic soils are benign, unless exposed due to various natural processes or anthropogenic activities and sulfuric acidity is produced, which has negative impacts on the environment. This paper examines the effects of organic matter, organic matter co-existing with live plants or live plants alone on sulfidic soil pH, redox and sulfate content under flooded conditions. In almost all cases, organic matter without plants induced ameliorative effects on sulfidic soil chemistry. In soils with or without organic matter, presence of plants led to higher Eh values, lower pH and higher sulfate contents. The reduction reactions of the added organic matter and the anoxia created by flooding were ineffective in reducing the amount of oxygen that was pumped into the rhizosphere via the aerenchymatous tissues in all the soils with plants. Under falling soil moisture regimes, e.g. during a drought event, presence of this type of plant species would aerate the reduced soil conditions. Aeration would then lead to oxidation of sulfides, producing sulfuric acid, which in turn would have negative impacts when released into the environment. One strategic option to reduce the amount of oxygen entering the soil would be to slash the shoots and leave them on the surface to help generate more alkalinity upon decomposition, even if the culm would continue to facilitate oxygen transport.

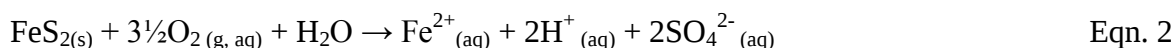
Keywords: Eh, live plants, organic matter, pH, sulfate content, sulfidic soil

Introduction

Sulfidic soils (pH > 4) of acid sulfate soils (ASS) are naturally occurring soils formed under reducing conditions (Pons, 1973; Baldwin and Fraser, 2009) and widely distributed associated with lakes, rivers and wetlands (Dent and Pons, 1995; Fitzpatrick et al., 2009; Fanning et al., 2017). Wilson (2005) and Joukainen and Yli-Halla (2003) reported these soils have been formed in the last 10 000 years after the last sea level rise. The microbially induced process through which sulfidic soils formed is shown in equation (Eqn.) 1 (Bloomfield and Coulter, 1973; Fanning and Fanning, 1989; Michael, 2013). When the sea level rose and inundated land, sulfate in the sea water mixed with iron oxide in the sediments and organic matter (OM), allowing sulfate reducing bacteria (SRB) to form iron sulfide (Canfield et al., 2006).



Under reducing conditions, sulfidic soils pose no problem unless exposed to atmospheric oxygen (Pons, 1973; Appleyard et al., 2004), e.g. by falling water levels such as during a drought event (Simpson et al., 2010), oxygen is pumped into the rhizosphere via the aerenchymatous by plants (Michael et al., 2017; Michael and Reid, 2018), land use means such as excavation, drainage or ploughing (Fitzpatrick et al., 2010) and the sulfides are oxidised, generating sulfuric acidity (Cook et al., 2000; Powell and Marten, 2005; Sullivan et al., 2009). Equation 2 shows the oxidation processes of the iron sulfide (FeS₂) and production of sulfuric acidity (Bloomfield and Coulter, 1973; Charoenchamratcheep et al., 1987; Michael et al., 2015).



Under natural soil use and management conditions, sulfidic soils are often flooded, resulting inundation due to the presence of excess water. Under such conditions, two major things happen; drowning and dying of plants that are unable to survive under excess water and striving of plants that are able to withstand flooding. When soils with water loving plants get flooded, these plants co-exist with the dead plant matter of those that died out as a result of drowning. When the flooded soil is without water loving plants, the OM from the dead plant matter exist alone, at least for some time. What happens to the sulfidic soil pH, redox and sulfate content under such scenarios on a short- or long-term is not often reported. We have reported in a long-term study (12 months) using *Phragmites australis* that live plants oxidise sulfidic soils and generate sulfuric acidity (Michael and Reid, 2018). However, the short-term effects (<6 months) were not investigated.

Therefore, this paper examines the effects of live plants alone or co-existing with OM and compares that with OM alone on sulfidic soil pH, redox and sulfate content under flooded conditions within a period of 6 months. This study was conducted as a preliminary study of the long-term study reported by Michael and Reid (2018).

Materials and Methods

Soil

The ‘sulfidic soil’ was collected from a ‘sulfuric subaqueous clayey soil’ at a depth of approximately 1000 mm in the Finnis River in South Australia at Wally’s Landing (35°24028.28”S; 138°49054.37”E). Details on soil classification using the Australian ASS Identification key and Soil Taxonomy are given in Michael et al. (2016). In addition, comprehensive lists of references containing further information on the soil morphology and geochemistry prior to rewetting (i.e. sites AA26.3 and FIN26) in Fitzpatrick et al. (2009) and after reflooding are given in Table 1 of Michael et al. (2015). The ‘sulfidic material’ (Soil Survey Staff, 2014) used is representative of typical global inland and coastal wetlands, in terms of sulfide and OM content.

The pH of the freshly collected sulfidic material measured in water 1:5 (pH_w) was 6.7. The water holding capacity based on wet and dry weight was estimated to be 49%. The estimation was made by setting soil samples at 100% field capacity after soaking in water and draining through a filter overnight. These soils were weighed to obtain the wet weight, and oven dried for 3 hours, then microwaved for 30 seconds to ensure removal of any residual moisture and reweighed to obtain a final dry weight. The residual OM content, estimated using weight loss-on-ignition method (Schulte & Hopkins, 1996) was 10.6%. The presence of

sulfidic materials (minerals) capable of producing sulfuric acidity was measured by treating 1 g of sulfidic soil with 5 ml of peroxide (1:5 w/w) as per Ahern et al. (2004). The pH following peroxide treatment (pH_{ox}) was 1.4, a strong indication of presence of high amount of oxidisable sulfides. The sulfate content of the sulfidic soil prior to use was 12 – 16 $\mu\text{mol g}^{-1}$ soil.

Organic Matter

To use as OM, the first three younger and fully open leaves of *P. australis* were collected and prepared as previously described (Michael et al., 2016). All the leaves were chopped into pieces, air-dried overnight under room temperature and then oven dried at 60 °C for three days. The dry pieces were finely chopped using an electric blender to pass through a ≈ 0.5 mm sieve. The nitrogen content of the OM analysed by ICP-OES using a 0.5 g samples ($n=3$) was estimated to be 3.7%. The carbon content can be approximated to be similar to grass (leaf) clippings from the data in Kamp et al. (1992).

Plant establishment

The *Phragmites* plants were initially raised as shoots (plantlets) by rooting root stocks in a rooting medium (compost: sandy loam 2:1 w/w). The well-rooted plantlets used in setting the experiments were approximately 8–12 weeks old. In each treatment, two plantlets each was transplanted which produced multiple shoots throughout the experiment. A dibble was used to make small holes, shoots or seedlings transplanted and the soil gently pressed to ensure the roots were in contact with the soil as would have been the case under any soil use condition. In all the experiments, the control treatments were not planted.

Experiments and treatments

The experiments described below were conducted in 500 mm tall (90 mm in diameter) stormwater tubes whose bottom ends were tightly capped. In all the tubes, the bottom 220 mm was filled with sand and the top 220 mm with 1300 g of moist sulfidic soil by weighing to add the exact amount in each tube. The treatments were replicated four times and set out in a complete randomized design under glasshouse conditions in polythene crates. In all the treatments, measurements were made only from the top 220 mm of the sulfidic soil. The treatments were always under flooded conditions with adequate amount of water ponding on the surfaces by regular addition of water (once in the morning and in the evening) for 6 months prior to data collection.

Experiment 1: This experiment was conducted with *P. australis* plants established with OM incorporated in the soil (80:1, soil: OM w/w) by bulk mixing. Bulk mixing was done by weighing out the amount of soil or OM needed using a portable scale at 80:1 (w/w), and thoroughly mixed in a 20 L mixing trough using a spade. Only the treatment soils were planted.

Experiment 2: In this experiment, *P. australis* plants were planted in the sulfidic soil in a similar manner under anaerobic (flooded) soil conditions but without added OM to compare to the results of experiment 1.

Measurements

The procedures used in the measurements were described in several studies (e.g. Michael et al., 2015; 2016; 2017; Michael, 2018 a, b, c). In all the measurements, only three treatments out of the four were used. Changes in redox potential (redox/Eh), pH and sulfate content were measured from the surface (0 – 20 mm), middle (50 – 100 mm) and deep (150 – 200 mm) soil profiles as previously described (Michael et al., 2015; 2016; 2017). Redox was measured using a single Ag/AgCl reference and platinum (Pt) electrode combination using an automated data logger (Michael et al., 2012). To measure the Eh, a handheld electric drill, with a drill bit head the size of the Pt electrode, was used to make holes through the tubes with care taken to avoid disturbing the soil. The Pt electrode was inserted in the holes and reference electrode inserted into the soil from the surface. This was allowed to equilibrate for 10 minutes and then Eh measured at 1 minute intervals for the next 10 minutes and averaged (Rabenhorst et al., 2009). These values were corrected for the reference offset to be relative to the potential of a standard hydrogen electrode by adding 200 mV (Fiedler et al., 2007). The stability and accuracy of the electrodes were maintained according to Fiedler et al. (2007). The pH was measured using 2 g soil in water (1:5 soil: water) with a pre-calibrated Orion pH meter (720SA model).

Sulfate was extracted according to the method of Hoeft et al. (1973) for soluble soil sulfate. Replicate samples (0.5 g each) were placed in tubes with 1.5 ml of an extraction solution (0.2 g CaH_2PO_4 , 12 g glacial acetic acid and 88.5 g deionized water). After 30 minutes, soil was sedimented by centrifugation for 5 minutes, and duplicate aliquots from the three replicates were transferred into 4 ml cuvettes and diluted with 1.5 ml of the extraction solution. The samples were mixed with 0.7 ml of 0.5 M HCl, and 0.7 ml of 0.1 M barium chloride-polyethylene glycol reagent was added and mixed again. After 10 minutes, the samples were mixed again and the absorbance read at 600 nm using a spectrophotometer. The readings were compared with a standard solution of 0 – 2 mM Na_2SO_4 . The initial sulfate content of the sulfidic soil ranged between 12 – 16 $\mu\text{mol g}^{-1}$ soil. The detection limit based on an absorbance reading of 0.1 of this method is 0.6 $\mu\text{mol g}^{-1}$ soil.

The root biomass was quantified as described by Michael et al. (2017) from the soil profiles from which the changes in Eh, pH and sulfate content were measured. Soil from these sections was placed in a sieve (0.05 mm) and held under a gentle running tap water and the soil carefully broken up to free the roots using the aid of forceps. The loose soil particles were allowed to drain through but roots that were trapped by the sieve and those that floated during washing were collected. These roots were taken, gently washed again to remove soil material, placed in weighing boats and oven dried for two days. The dry weights were taken by weighing and weights of the replicates were pooled, averaged and kept as the final data.

Statistical analyses

The Eh values obtained over a 10 minutes period were averaged and a treatment average obtained by taking the mean of the three replicates as we reported. Similarly, treatment average pH and sulfate content were obtained by taking the mean of the three replicates. To compare the treatment means, significant differences ($p < 0.05$) between treatment means of each profile were determined by two-way ANOVA using statistical software JMPIN, AS Institute Inc., SAS Campus Drive, Cary, NC, USA. If an interaction between the treatments and profile depths was found, one-way ANOVA with all combination was performed using

Turkey's HSD (honest significant difference) and pairwise comparisons. The values presented in all the figures are mean $\pm$ s.e. of three replicate measurements. An asterisk indicates significant difference ($p < 0.05$) between treatment and control at same depth.

Results and Discussion

Effects of organic matter co-existing with live plants on pH

The aim of the two experiments was to assess the effects of OM co-existing with live plants under natural anaerobic soil conditions or following flood events with the common knowledge that the sulfidic soil would remain reduced.

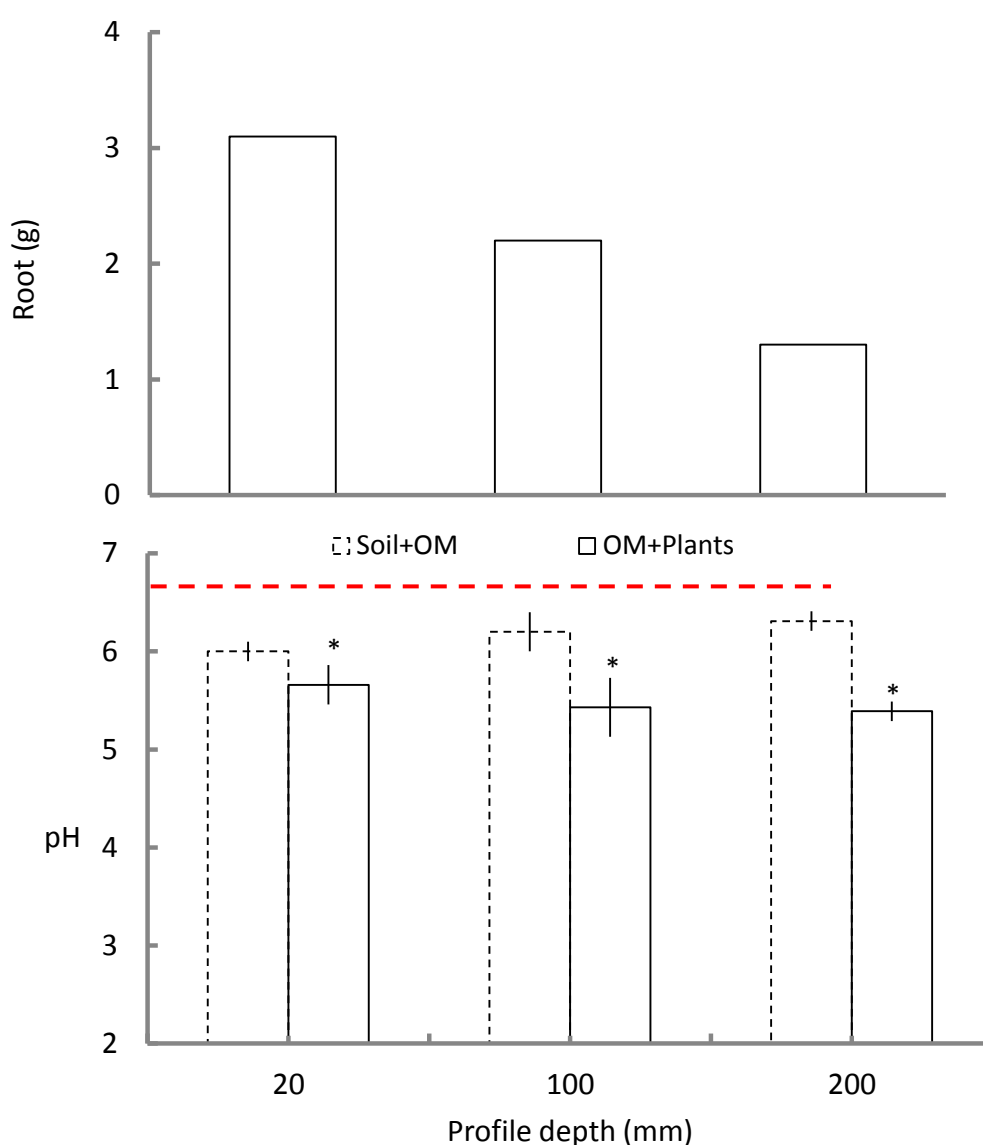


Figure 1. Effects of organic matter with or without live roots on pH under flooded soil conditions. The dotted line is the initial pH.

In the presence of plants capable of pumping oxygen into the rhizosphere, soils are expected to be oxidised, lowering the soil pH. In the planted soil, the change in pH was near 6 units at the surface and near 5 units at the deep, respectively (Fig. 1). In the unplanted soil, OM addition lowered the pH well below the initial pH of 6.7 units. As shown in Fig. 1,

biomass was distributed as would be in young plants, with more roots within the surface soils than at the deep. There was however no clear relationship with the changes in pH measured and the biomass distribution.

Effects of organic matter co-existing with live plants on redox potential

Under the flooded soil conditions, biomass distribution and soil redox had a clear relationship (Fig. 2). Redox was reduced where the biomass was bigger and got highly reduced in the deep soil of small biomass. The co-existence of OM and live plants did increase the pH (Fig. 1) but the reduction reaction of flooding was dominant at deep soil. Existence of OM alone sustained the reduced conditions of the sulfidic soil, Eh ranging between -10 mV to -80 mV (Fig. 2).

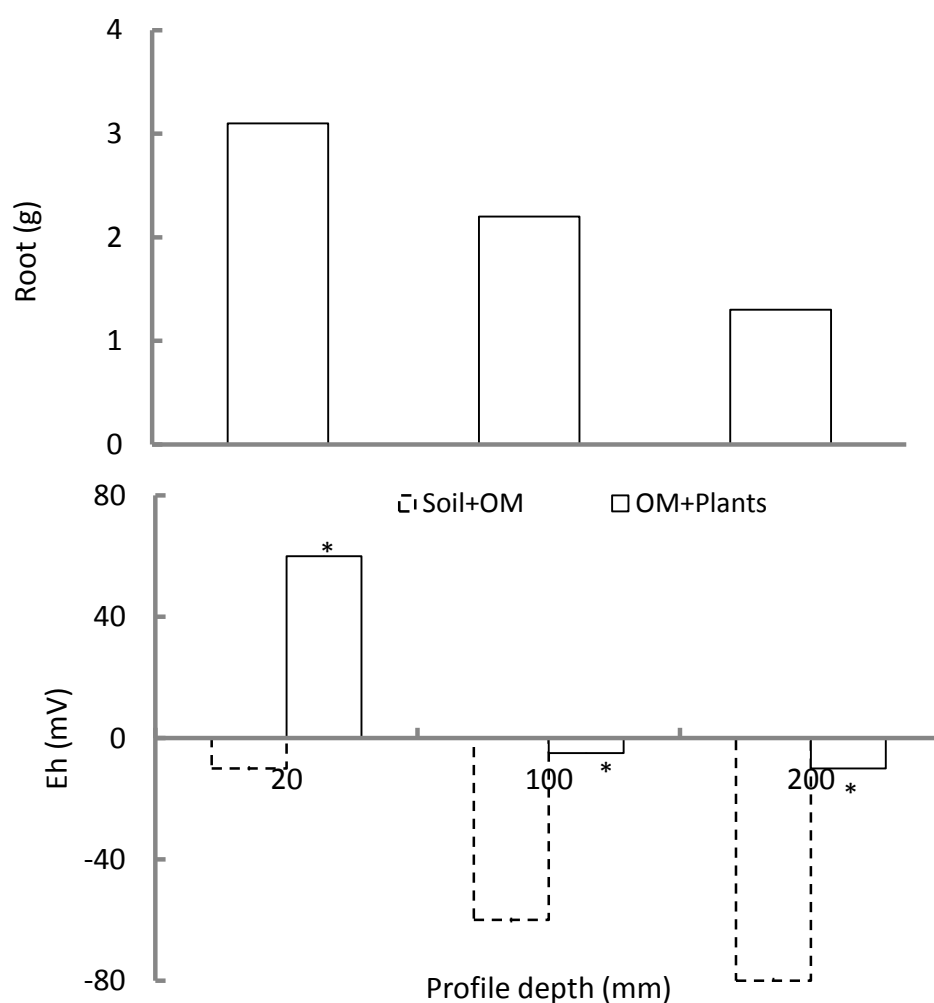


Figure 2. Effects of organic matter with or without live roots on redox potential under flooded conditions.

Effects of organic matter co-existing with live plants on sulfate content

In the OM amended soils without live plants, the sulfate content was near $3 \mu\text{mol g}^{-1}$ soil throughout the profiles (Fig. 3). In the planted soils with OM, the sulfate content was reduced to near $6 \mu\text{mol g}^{-1}$ soil and there was no change at deep soils. In the soil with both

OM and plants, the sulfate content was highly reduced in the presence of bigger biomass, and the opposite happened with smaller biomass, respectively (Fig. 3).

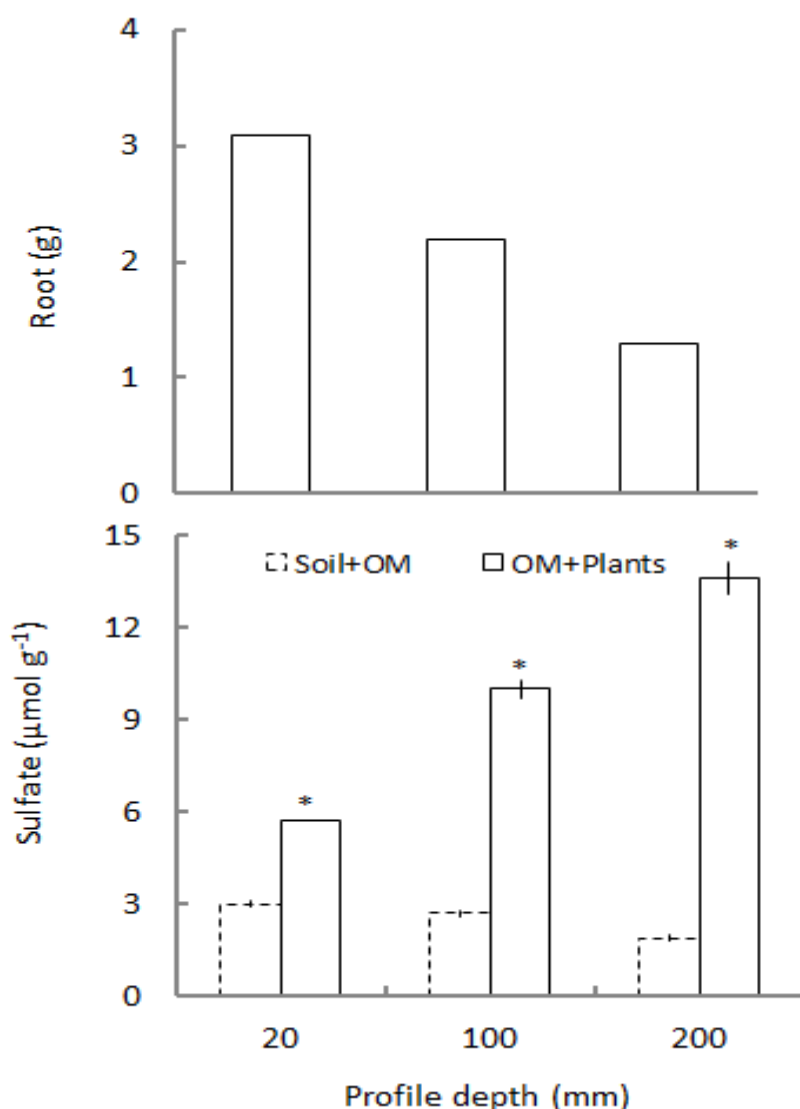


Figure 3. Effects of organic matter with or without live roots on sulfate content under flooded soil conditions. The initial sulfate content range from 12-16 $\mu\text{mol g}^{-1}$.

Effects of live plants alone on soil pH

Changes in soil pH measured in the absence of OM are shown in Fig. 4. The biomass distribution was fairly the same throughout the soil profiles in the absence of OM. In the unplanted soil, the pH remained nearly unchanged with a small decrease within the surface soil. In the planted soil, pH decreased, more so at the deep soil where the biomass was bigger (Fig. 4). Unlike the previous experiment (shown in Fig. 1), less biomass was produced in the absence of OM.

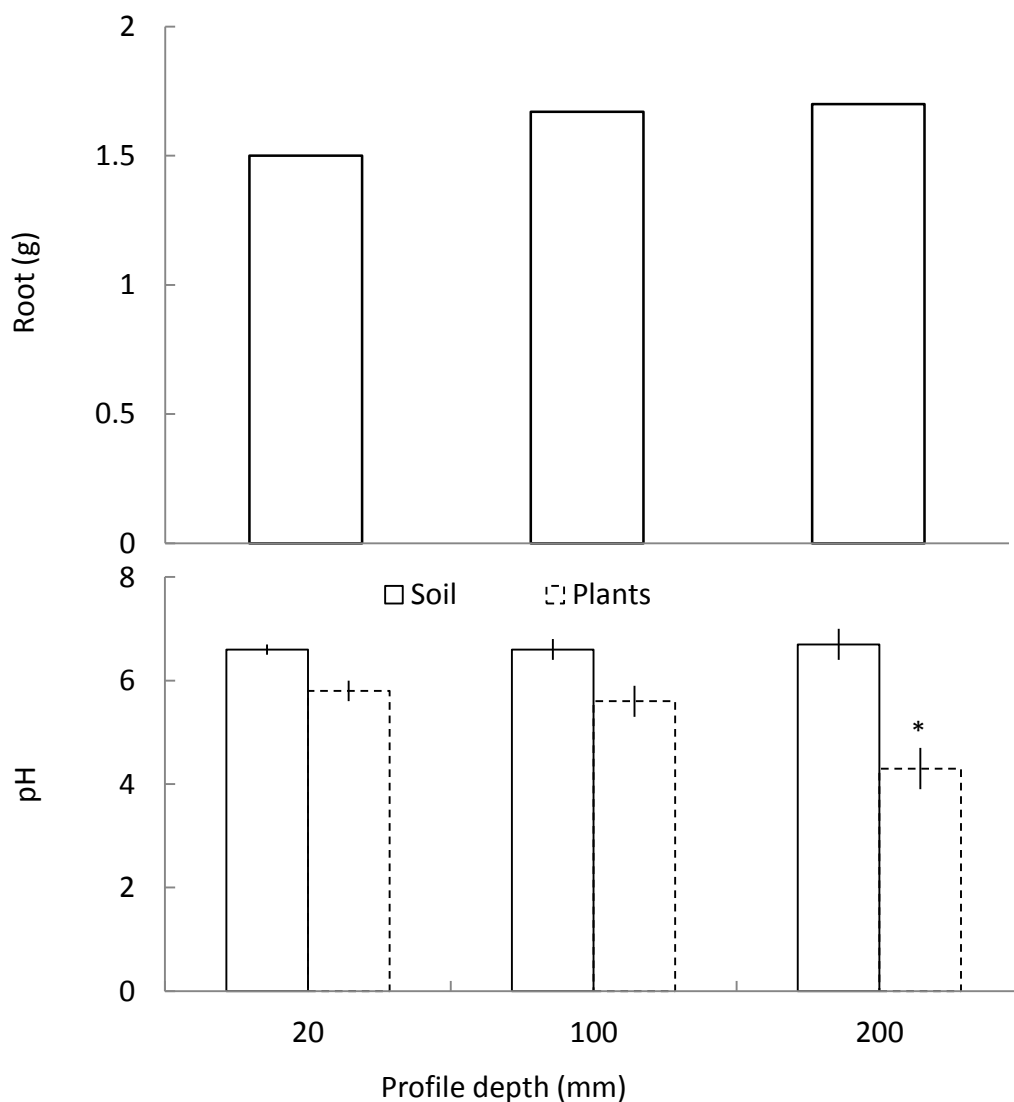


Figure 4. Effects of live roots on pH of soil without added organic matter under flooded conditions.

Effects of live plants alone on soil redox potential

Under the flooded soil conditions, the redox of the planted soil was oxidised within the surface to reduce at deep, Eh ranging from 60 mV to 10 mV (Fig. 5). The influence of biomass on the changes in redox was not clearly seen. In the control soil, redox was highly reduced, with the overall changes ranging from -100 mV at the surface to -70 mV depth.

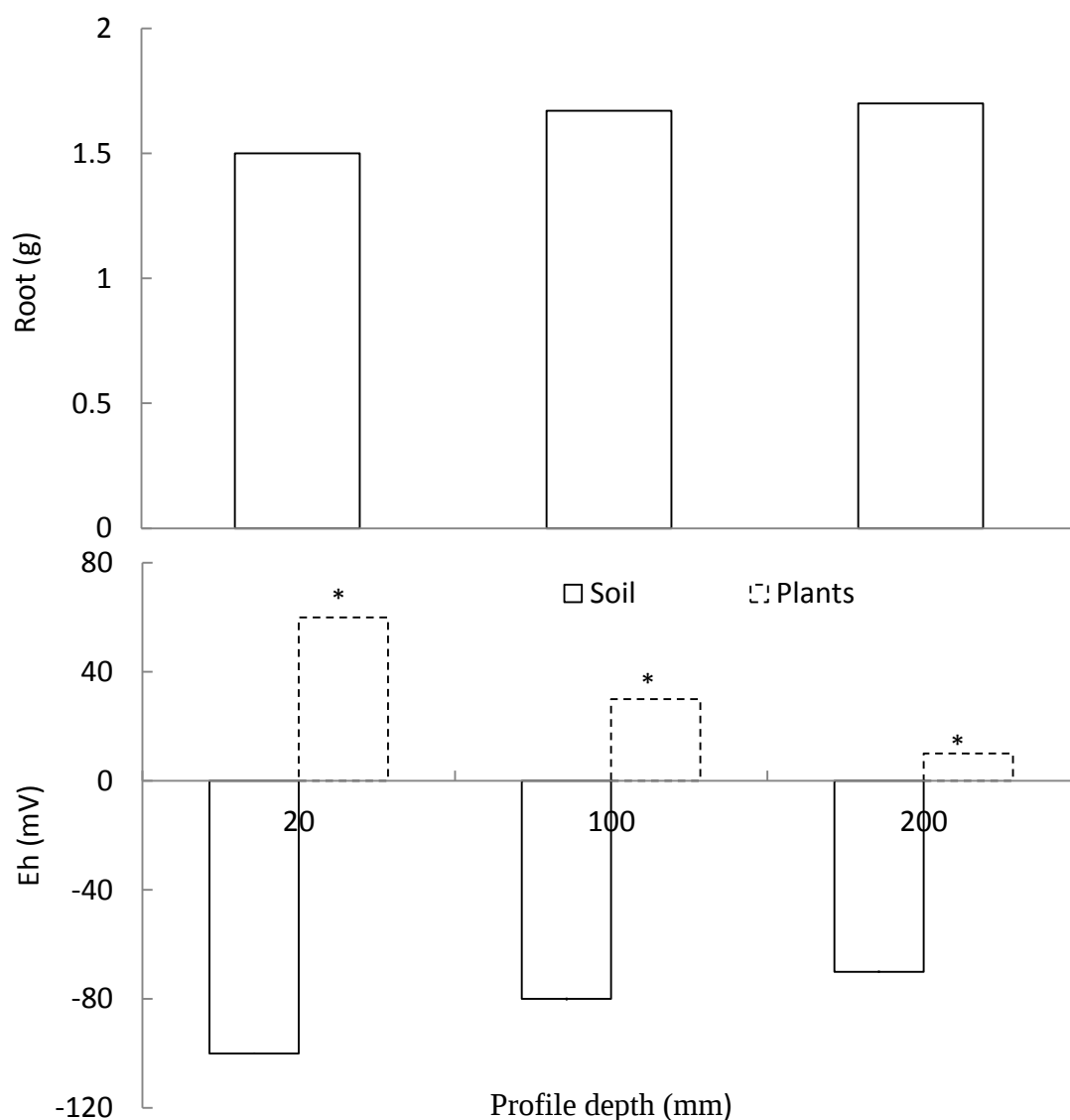


Figure 5. *Effects of live roots on redox potential of soil without added organic matter under flooded soil conditions.*

Effects of live plants alone on soil sulfate content

Under the flooded soil conditions, sulfate content was higher in the planted soil at the surface soil with smaller biomass than at deeper profiles of bigger biomass (Fig. 6). Generally, the changes in sulfate content were small in the profiles of smaller biomass, especially within the surface soil. In the unplanted soil, sulfate content was small and decreasing with soil depth.

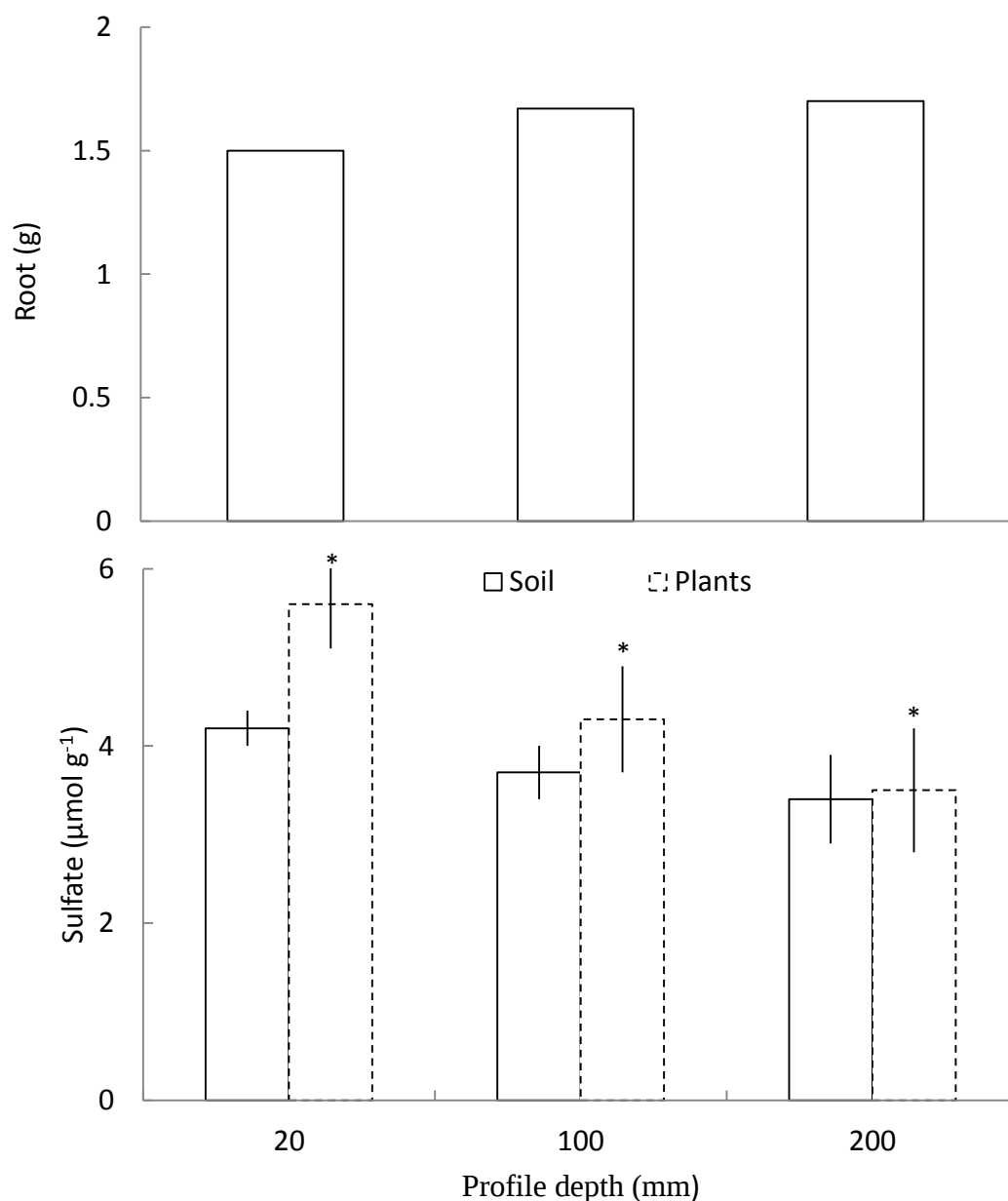


Figure 6. Effects of live roots on sulfate content of soil without added organic matter under flooded soil conditions. The initial sulfate content range from 12-16 $\mu\text{mol g}^{-1}$ soil.

Sulfidic soil status under reduced soil conditions

Michael (2013) reviewed the negative impacts of the sulfuric acidity produced and pointed out basic management strategies that are available in managing either sulfidic soil materials or the sulfuric soil material, respectively. The former is managed by water table management (flooding) and the later by application of an alkalizing agent, e.g. such as lime (Shamshuddin et al., 2004). Under soil use conditions, flooding is not often favoured because it limits land uses and availability of refined lime is expensive to afford in poor economies, e.g. in the developing countries where ASS is found. We have pointed out in several studies that addition of OM, which is relatively cheap and readily available is an alternative management strategy to manage oxidation and acidity (e.g. Michael et al., 2015; 2016; 2017; Michael, 2015; 2018a, b, c). We demonstrated through some of these studies (e.g. Michael et al., 2015) that addition of OM followed by flooding revert sulfuric soil to sulfidic soil. The

mechanisms for these being consumption of protons (H^+) by the reduction reactions of flooding and reduction of sulfate to sulfide by sulfate reducing bacteria (SRB) using the added OM as a metabolic substrates (Michael, 2018b).

Mechanisms of changes in sulfidic soil chemistry associated with organic matter

The experiment with OM addition but without live plant sustained the pH of the sulfidic soil within the surface and even increased it at the deep soil (Fig. 1). These changes were consistent with the changes in pH measured in the experiment without OM addition (Fig. 4). As shown in Fig. 2, addition of OM reduced the Eh, the changes ranging from -10 mV within the surface to -80 mV at depth. Compared to these changes, the soil remained highly reduced without added OM, the changes ranging from between -100 mV at the surface to -70 mV at depth (Fig. 5). In both studies, the changes in Eh at deep soil are quite similar except within the surface (0 – 20 mm). The mechanisms for the differences in the surface soils seem to come from the added OM (Michael et al., 2015; Jayalath et al., 2016). OM addition increased porosity for oxygen to penetrate the surface soil and reduce it to -10 mV, whereas in the absence of added OM, there was no pore space due to the flooded nature of the soil for this to happen, making the soil to remain highly reduced, with Eh near -100 mV. Sulfate reducing bacteria are known to work when the soil pH is >5 units and the redox is <-100 mV (Michael, 2018b). When OM was added, the sulfate content was nearly depleted to well below 3 $\mu\text{mol g}^{-1}$ soil (Fig. 3). In the absence of OM, the sulfate content was high but reduced to near 4 $\mu\text{mol g}^{-1}$ soil (Fig. 6). The probable reason for this is the presence of the residual OM content of 10.6%, which was utilized by soil microbes to reduce the sulfate content in the absence of added OM. The changes in pH and Eh in soil with OM were within the ranges of SRB to function, making the changes in sulfate content measured to be induced by SRB (Michael et al., 2016; 2017). In addition to the reducing reactions created by flooding, oxygen was consumed by aerobic and facultative microbes that initially acted on the OM, creating micro-niches sufficient for SRB to function (Michael, 2018b).

Mechanisms of changes in sulfidic soil chemistry associated with live plants

Under the flooded soil condition, greater root biomass was produced when OM was added at surface soil, however, smaller biomass was measured at deeper soil (Fig. 1). The type of biomass distribution measured is typical of newly established plants. In the unamended soil, biomass was statistically equal throughout the soil profiles (Fig. 4). These results seem to indicate that the OM within the surface was adequately decomposed, probably by aerobic microbes, making available nutrients to support the production of bigger biomass, compared to the deep soils where decomposition is slow, and less or low nutrient availability, resulting in smaller biomass production. Despite the flooded soil conditions, plants co-existing with OM lowered the soil pH (Fig. 1) when the opposite happened in the soil without plants (Fig. 4). The overall change was in the range of 6 units at the surface to near 5 units at the deep soil (Fig. 1). In the absence of OM, plants significantly acidified the soil, the changes in pH ranging between 5.8 units at the surface soil and 4.3 units at the deep (Fig. 4). Comparatively, even if plants acidified the soil, OM was able to offset that and sustain the pH, conducive for root growth.

Flooded soils are expected to remain reduced because of the reduction reactions and lack of oxygen diffusion. In the presence of plants capable of delivering oxygen into the

rhizosphere, at least a certain degree of oxidation is expected (Hanhart et al., 1997). In almost all cases, presence of plants oxidised the soil, more so in the absence of OM. Co-existence of OM and plants oxidised the surface soil (Fig. 2). This might have been possibly facilitated by the combine effects of oxygen that penetrated the soil via the aerenchymatous tissues, porosity created by the added OM and by the roots. In the soil without added OM, the soil was reduced and the changes in Eh were high, compared to the results shown in Fig. 5. This variability demonstrates that the plants delivered oxygen, sufficient to oxidise the soil however offset by OM (Yuan et al., 2015a, b).

The changes in sulfate contents measured in the soil amended with OM and planted without OM are shown in Figs. 3 and 6, respectively. Except in the surface soil, plants had minimal effect on the sulfate content soil amended with OM, following an observation that in the profiles of bigger biomass, a smaller amount of sulfate was quantified (Fig. 3). In the unamended soil, sulfate content was high in the presence of plants and was decreasing at deep soil but higher than that measured in the control soil (Fig. 6). Michael (2018b) pointed out that sulfate reduction occurs when the condition, i.e., Eh < -100 mV and pH at least >5 is sufficient for SRB to function. The high sulfate content shown in Fig. 6 corresponds to the high redox values of Fig. 5, the major reason why SRB did not function under these soil conditions. The results of the planted soil following OM amendment being similar show the same mechanism was operating under the conditions of the experiment shown in Fig. 3.

Management of the mechanisms underlying the changes in ASS chemistry

This study shows that plants will accelerate the fall in soil moisture because of water use in photosynthetic reactions, evapotranspiration and oxygenation of the rhizosphere via the modified structures, leading to oxidation. The results further show that if oxidation happens in soil with live plants co-existing with sufficient OM, e.g. from dead plants that have drowned as a resulting of flooding, then the negative impacts of the oxidation process will be offset. On the other hand, the results indicate that live plants existing alone could potentially cause oxidation and acidification of the soil. The underlying mechanism for the changes in soil chemistry measured in the presence of *P. australis* is that this plant used its modified structures (aerenchymatous tissues) to pump oxygen into the rhizosphere, leading to oxidation and lowering of the pH when without OM (Armstrong et al., 1996; Mark et al., 1994). When oxygen was pumped into soil with sufficient OM, soil microbes, especially the facultative ones, used the available oxygen to oxidise the OM, reducing the redox and sulfate content, thereby decreasing the pH. Under flooded soil conditions, decomposition of OM is slow and release of nutrients from the OM to support root growth is small (Michael and Reid, 2018). The bigger biomass produced by plants co-existing with OM (Fig. 1) compared to without OM (Fig. 4) seems to suggest that sufficient nutrients were available from aerobic decomposition using oxygen that were pumped into the soil. These nutrients were utilized by the plants to produce the bigger biomass shown in Figs. 2 – 3. In the absence of OM, the reducing conditions created by flooding were not sufficient to consume the oxygen that was pumped into the soil, resulting in oxidation, which led to lowering of the pH and no effect on the sulfate content (Figs. 4 – 6). Under these conditions, nutrient limitation resulted in small biomass production, as shown in Fig. 4.

The management implications revolve around the balance between OM turnover and live plants (Michael and Reid, 2018). Under normal soil use and management conditions, OM

addition from mulch, turnover of plant matter or organic compound secretion by plant roots enable soil microbes to act and modify the soil chemistry (Reid and Butcher, 2011; Pocknee and Summer, 1997). These processes are sufficient to create micro-environments conducive to alter the pH (Yan et al., 1996), redox and sulfate content, important for management of sulfidic soil. In flooded soils, reduction reactions consume available oxygen and sustain alkalinity. This study showed flooding did not sustain sulfidic soil alkalinity when *P. australis* was present without OM. An option to manage the oxygen entry into the soil via the modified anatomical structures is to remove the shoots by cutting them off, even if the remaining culm will still pose problems (Michael and Reid, 2018). This strategy will not only reduce oxygen entry but the dead shoots will help build up the OM, which will further reduce the soil when microbes act on the resources and generate alkalinity.

Conclusion

In contrast to the positive effects on sulfidic soil of OM derived from dead plant material, turnover of OM as leaf litter or secretion of organic compounds from live plants, the growth of live plants with roots capable of transporting oxygen downwards via aerenchymatous tissue in sulfidic soil induces acidity rather than sustaining alkalinity. OM addition gave rise to more root biomass, resulting in more oxygen into the rhizosphere of the plants. Under falling water regimes such as during a change in climatic conditions, an important management option would be to slash the plants and return them as mulch, generating alkalinity through the decomposition processes. Culms would continue to transport oxygen into the soil; therefore, reworking on the soil following slashing to prevent oxygen penetration is an important management option.

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Effect of Organic and Mineral Fertilizers on the Growth of *Acer Platanoides* L.

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Abstract

A field experiment was carried out with *Acer platanoides* L. saplings fertilized using organic fertilizer 'Siapton' in different variants: control (K); variant 1 (V_1) - low dose of "Siapton" (1ml); variant 2 (V_2) - high dose of "Siapton" (50ml); variant 3 (V_3) - high dose of "Siapton" and mineral fertilizer "Krystalone" and variant 4 (V_4) - high dose of "Siapton" and organic fertilizer "Biohumus". All fertilized variants show better growth in mean diameters (root collar diameter (D_0) and breast height diameter (BHD)), average height and wood biomass accumulation with the exception of V_1 . The dose turns out to be definitive in relation with the fertilization effect. Good results are obtained by combining two organic fertilizers (V_4) during the first two years of fertilization. Variant 3 (combination with mineral fertilizer), however, has a longer duration and is manifested in a long time after application of fertilization (especially in the third year after treatment) and is also recommended to be applied in practice. The increment of height is most pronounced in V_4 (a combination of two organic fertilizers) for a longer period, too: an increment of 0.43 m versus 0.07 m for the control during the third year. This gives the reason to recommend organic fertilization in improving the growth characteristics of Norway maple for the needs of forestry and urban planning where good growth and accumulation of woody biomass is desired.

Key words: increments, stem form coefficients, tree growth characteristics, total volume

Introduction

Fertilizing of forest-tree vegetation is mainly used in forest nurseries or in urban environments – mainly in public parks and gardens. In spite of the non-extensive use of fertilization, it has been assumed that in general it has a positive influence on the metabolism, growth and development of woody plants (Donov et al., 1975, Miller and Tarrant, 1983, Gebauer and Schulze, 1991, Balster et al., 2009). Fertilization has an immediate positive effect on growth indicators of trees, such as the basal area increment (for example, which effect may last for a very long time), sometime up to 20 years (Brooks and Coulombe, 2009, Ponton et al., 2019). Significant positive effect on soil properties can be achieved by using organic fertilizers (Kachova, 2018) or some mulch types (Awopegba et al., 2016). An important question in forest management when fertilization be applied is to determine the effect of fertilizers on the overall development of forest plantations. There are also a number

of other questions, such as: What is the best ratio of nutrients used in the fertilizer combination? What is the best time for fertilizing? What are the most appropriate doses? etc. Essential is also a question about the impact of fertilization on growth in height and thickness of tree saplings, or rather how the variation of doses or fertilizer combination is in line with the height and diameter changes of the saplings. In Bulgaria, these issues have been studied mainly with using mineral fertilizers (Dakev, 1972, Dakev and Badjov, 1975, Denev, 1966, Broshtilov, 1986, Tsanov and Broshtilova, 1986, Zhelyazkov and Markova, 1993, Petterson and Dimov, 2013). The use of organic fertilizers is not widely applicable and the issues involved still remain poorly studied and experimentally unclear. Special issues is the effect of organic fertilizers on soil organic matter because the majority of Bulgarian soils have very low organic content and fertilization is occurred to be an good practice for improving the agrochemical status of cultivated soils (Petkova, 2016). In addition, the effect of fertilization also depends on the tree species (Cukor et al., 2017), and the Norway maple is poorly studied.

The species *Acer platanoides* L. can be used for afforestation of eroded terrains, production of wood and musical instruments, and in urban landscaping due to its high decorative crown. It is relatively resistant to harmful external influences, especially urban environments (Nowak and Rowntree, 1990, Dirr, 1998). However, the species is more susceptible to pathogenic fungi and insects along heavy-traffic roads in comparison with the trees growing along a road with pedestrian traffic (Wilkaniec et al., 2018). In Bulgaria, the species is widely distributed from 500 to 1500 m a.s.l. mainly in fresh habitats (Milev et al., 2004). It is used mainly for the creation of mixed plantations, predominantly with oaks, beech and silver fir, and is one of the most valuable for forestry (Pandeva, 2004). These plantations are successfully used for the collection of reproductive seed material, however, conservation activities are needed to be carried out there (Tomov et al., 2014). The growth and development of the species and the action of various abiotic and biotic factors on it has not been well studied worldwide. The effect of composted green waste on the growth of saplings of *Acer platanoides* has been studied and a positive effect on growth in height and diameter, as well as increased survival rate, has been found (Ashwood et al., 2018). It is ascertained that as non-native species *Acer platanoides* has been more phenotypically plastic than some native species especially when fertilization is used (Cook-Patton and Agrawal, 2011). Long et al., (2011) studied the effect of liming on sugar maple (*Acer saccharum* Marsh.) and found that over the 23-year period its basal area increment increased significantly whereas in the other tree species this fertilization was ineffective. Dakev and Badjov (1975), using N-mineral fertilizer, found that the fertilized and non-native saplings of *Acer platanoides* had approximately the same weight. The influence of organic and mineral fertilization on the development of soil microflora in the cultivation of seedlings of Norway maple was studied (Kachova et al., 2017). The effect of composted green waste on the growth of saplings of *Acer platanoides* has also been investigated and a positive effect on growth of height and diameter, as well as increased survival rate, has been found (Ashwood et al., 2018).

The aim of this work is to follow the effect of organic fertilizer (alone and in combination with other organic fertilizer or mineral fertilizer) on the growth of Norway maple over a three-year period.

Organic fertilizer 'Siapton' was used, which is new to the Bulgarian market, but has proven properties for improving the productivity and sustainability of agricultural crops. It is

applied for the first time for tree plants and it is of interest to trace its effect on forest plantations as well.

Material and Methods

The saplings of Norway maple were planted as a field experimental in the yard of the Forest Research Institute – BAS, Sofia, at the end of March 2016. The scheme used is 7 rows of 7 saplings or a total of 49 saplings at a distance of 1 m from each other (Kachova et al, 2017). Saplings are fertilized two times: in the beginning of the growing season (08.06.2016) and 20 days later (28.09.2016). The variants of experience are as followed:

- Control (K) – untreated saplings;
- Variant 1 (V₁) – Fertilizing with ‘Siapton’ at a dose of 1 ml per sapling;
- Variant 2 (V₂) – Fertilizing with higher dose (50 ml) ‘Siapton’ per sapling;
- Variant 3 (V₃) – ‘Siapton’ 50 ml + 0.5 mg mineral fertilizer ‘Krystalone’ dissolved in 500 ml of water;
- Variant 4 (V₄) – ‘Siapton’ 50 ml + 50 % solution of ‘Biohumus’.

The organic fertilizer ‘Siapton’ R is new to the Bulgarian market and is recommended for foliar and soil application. Its composition is: total, organic, ammonium nitrogen up to 4 %; organic carbon – 25 %; aminoacids of animal origin – 54.34 %. This fertilizer has shown good results for agricultural crops to increase yield and quality of production and to increase plant defense in stressful situations. The mineral fertilizer ‘Krystalone’ contains mainly N, P, K, Mg and more than 10 other trace elements in smaller quantities (<1 %). ‘Biohumus’ is a fertilizer of red California worm, widely used in agriculture.

The experience was set up on *Vertisols* with the following characteristics: pH = 6.4; organic carbon = 3.93 %; total nitrogen content = 0.12 %. The site is in the southeastern part of the metropolitan city – with a moderate continental climate; altitude of 630 m a.s.l.; average precipitation 693 mm, and temperatures in the metropolitan city 0.1 to 5 °C higher than in the rest of the valley (Climate and Microclimate of Sofia, 1983).

To calculate the mean diameter of the saplings, a method from the descriptive statistics was used, calculated as an average arithmetic and separately using the basal area of the saplings after the formula (1):

$$d_{cp} = \sqrt{\frac{4G_{av}}{\pi}} = \sqrt{1.274 \cdot G_{av}}, \quad (1)$$

where G_{av} is a basal area.

The average height was calculated as an arithmetic average. The Lorey's formula was not used because there were saplings that did not reach a breast height (1.30 m) and applying the formula gave very large deviations.

The growing stock was calculated by Huber's formula (2) for stem volume:

$$V = G_{1/2} \cdot H_{av}, \quad (2)$$

where: $G_{1/2}$ is a basal area calculated at $\frac{1}{2}$ of the height of each sapling, and H_{av} is average height. Then the volumes of all saplings from the variant were summed and the total volume or the growing stock for each variant was obtained.

For statistical processing of the results, programs Statistics 4.0 and Excel used.

Results

Measurements of the diameter of the saplings were done every month in 2016 and 2017 and twice during the vegetation period of 2018. The diameter is measured in two places: at the root collars and at breast height (1.30 m). The variation in mean diameter by variants in 2016 and 2017 and 2018 are given in Tables 1, 2, 3 and 4. Initially, during planting, the saplings of the different variants begin their growth from uneven diameters at the root collar. As of June 2017, however, V_2 and V_4 outweighed the control in their growth in root collar diameter (RCD). Particularly pronounced is the higher RCD increase in 2018, V_2 , V_3 and V_4 predominate significantly over the control. The highest are the values of V_3 – combination of ‘Sapton’ with mineral fertilizer. The combination of two organic fertilizers (V_4) also shows good results. The lowest result is V_1 – a low dose of ‘Siapton’. It is obvious that at this low dose – 1ml the effect of the organic fertilizer is minimized and practically does not exist.

The mean breast height diameter (BHD) is also unequal for the variants in the beginning of the growth – 31.03.2016. Highest value shows the control (Table 3). The saplings of V_4 started their growing with the lowest value of BHD. However, this was compensated in the beginning of the second year (02.05.2017), when the saplings of V_4 also outrun the control (Table 4). Here again, the effect of fertilization in 2018 is most pronounced when all variants are significantly above the control in relation of BHD. The influence of fertilization is strongest again in V_3 and in V_4 .

If data about the mean diameters are given as an increment during the years, then the following results are obtained (Table 5).

The highest growth rate of RCD and BHD for the second and third years after fertilization have V_2 , V_3 and V_4 . The highest RCD in organic fertilization is in the first and second year of fertilization, alone V_2 and in combination with ‘Biohumus’ – V_4 . However, in the third year (2018) variant V_3 (‘Sapton’ + mineral fertilizer) showed the best growth of saplings in relation to the RCD (2.20 mm). The variants with organic fertilization (V_2 and V_4) also have a good RCD increments and in the third year (2018) higher than that of the control approximately 2 times. The control lagged behind the growth of RCD and BHD in the first and second years, and in the third year it was markedly the lowest.

Table 1. Dynamics of RCD (cm) in 2016.

Variant	Date						
	31.03	27.04	01.06	30.06	01.08	01.09	05.10
K	125 ±0.17	1.26 ±0.24	1.29 ±0.16	1.31 ±0.15	1.31 ±0.15	1.33 ±0.15	1.33 ±0.15
1	1.17 ±0.11	1.18 ±0.12	1.20 ±0.12	1.25 ±0.11	1.25 ±0.12	1.26 ±0.12	1.26 ±0.12
2	1.17 ±0.17	1.18 ±0.17	1.19 ±0.18	1.24 ±0.16	1.25 ±0.15	1.28 ±0.15	1.29 ±0.15
3	1.28 ±0.22	1.29 ±0.22	1.31 ±0.21	1.36 ±0.22	1.39 ±0.24	1.39 ±0.24	1.40 ±0.24
4	1.11 ±0.15	1.19 ±0.16	1.22 ±0.18	1.27 ±0.17	1.27 ±0.17	1.28 ±0.17	1.28 ±0.17

Table 2. Dynamics of RCD (cm) in 2017 and 2018.

Variant	Date							
	31.03	02.05	30.05	06.07	01.08	31.08	05.10	19.06.2018
K	1.35 ±0.14	1.35 ±0.13	1.37 ±0.14	1.41 ±0.15	1.44 ±0.17	1.45 ±0.17	1.46 ±0.17	1.55 ±0.16
1	1.29 ±0.12	1.28 ±0.12	1.28 ±0.12	1.32 ±0.13	1.34 ±0.14	1.39 ±0.09	1.40 ±0.09	1.50 ±0.10
2	1.31 ±0.15	1.32 ±0.15	1.36 ±0.12	1.49 ±0.11	1.55 ±0.12	1.57 ±0.12	1.58 ±0.11	1.65 ±0.15
3	1.40 ±0.24	1.41 ±0.23	1.45 ±0.23	1.53 ±0.22	1.61 ±0.24	1.63 ±0.26	1.63 ±0.26	1.84 ±0.32
4	1.29 ±0.17	1.30 ±0.17	1.35 ±0.19	1.49 ±0.22	1.58 ±0.26	1.59 ±0.26	1.59 ±0.26	1.73 ±0.29

Table 3. Dynamics of BHD (cm) in 2016.

Variant	Date						
	31.03	27.04	01.06	30.06	01.08	01.09	05.10
K	0.42 ±0.26	0.43 ±0.26	0.45 ±0.21	0.46 ±0.22	0.46 ±0.22	0.47 ±0.22	0.47 ±0.22
1	0.40 ±0.21	0.46 ±0.24	0.48 ±0.22	0.51 ±0.22	0.51 ±0.22	0.51 ±0.22	0.52 ±0.22
2	0.37 ±0.20	0.40 ±0.16	0.43 ±0.16	0.44 ±0.06	0.46 ±0.06	0.46 ±0.17	0.46 ±0.17
3	0.41 ±0.27	0.43 ±0.21	0.45 ±0.25	0.48 ±0.25	0.49 ±0.25	0.49 ±0.25	0.49 ±0.25
4	0.32 ±0.26	0.33 ±0.26	0.37 ±0.17	0.41 ±0.22	0.41 ±0.22	0.42 ±0.25	0.42 ±0.19

Table 4. Dynamics of BHD (cm) in 2017 and 2018.

Variant	Date							
	31.03	02.05	30.05	06.07	01.08	31.08	05.10	19.06.2018
K	0.48 ±0.27	0.48 ±0.23	0.49 ±0.23	0.50 ±0.23	0.52 ±0.24	0.52 ±0.24	0.52 ±0.24	0.57 ±0.26
1	0.52 ±0.22	0.53 ±0.30	0.54 ±0.15	0.55 ±0.15	0.58 ±0.15	0.59 ±0.15	0.59 ±0.15	0.65 ±0.17
2	0.47 ±0.17	0.50 ±0.07	0.53 ±0.06	0.61 ±0.07	0.67 ±0.08	0.68 ±0.08	0.70 ±0.08	0.80 ±0.11
3	0.50 ±0.14	0.52 ±0.22	0.59 ±0.24	0.63 ±0.26	0.69 ±0.28	0.69 ±0.28	0.70 ±0.28	0.81 ±0.34
4	0.46 ±0.09	0.49 ±0.09	0.57 ±0.13	0.63 ±0.15	0.68 ±0.19	0.68 ±0.19	0.69 ±0.19	0.78 ±0.25

Table 5. Increment (mm) in diameter during 2016, 2017 and 2018.

Variant	2016	2017	2018
Increment of RCD, mm			
K	0.80	1.1	0.80
1	1.00	1.3	1.00
2	1.20	2.9	1.60
3	1.20	2.2	2.20
4	1.70	3.0	1.50
Increment of BHD, mm			
K	0.40	0.50	0.50
1	0.90	0.70	0.60
2	0.80	1.30	1.50
3	0.70	1.90	1.10
4	1.00	2.30	0.90

The height of the saplings measured during the period was statistically processed and the data on the average height during the years is given in tables 6 and Table 7.

Table 6. Dynamics of average height (m) in 2016

Variant	Date						
	31.03	27.04	01.06	30.06	01.08	01.09	05.10
K	1.57 ± 0.17	1.61 ± 0.23	1.62 ± 0.24	1.63 ± 0.24	1.66 ± 0.27	1.66 ± 0.27	1.67 ± 0.21
1	1.55 ± 0.70	1.60 ± 0.19	1.64 ± 0.64	1.64 ± 0.21	1.64 ± 0.21	1.64 ± 0.21	1.65 ± 0.22
2	1.42 ± 0.09	1.46 ± 0.04	1.48 ± 0.04	1.51 ± 0.09	1.52 ± 0.09	1.53 ± 0.08	1.54 ± 0.08
3	1.47 ± 0.08	1.53 ± 0.06	1.55 ± 0.11	1.55 ± 0.09	1.58 ± 0.06	1.58 ± 0.06	1.58 ± 0.08
4	1.43 ± 0.01	1.48 ± 0.01	1.51 ± 0.10	1.56 ± 0.14	1.56 ± 0.16	1.57 ± 0.16	1.57 ± 0.16

Table 7. Dynamics of average height (m) in 2017 and 2018.

Variant	Date							
	31.03	02.05	30.05	06.07	01.08	31.08	05.10	19.06.2018
K	1.67±0.20	1.67±0.20	1.69±0.21	1.69±0.23	1.70±0.23	1.70±0.23	1.70±0.23	1.77± 0.18
1	1.65±0.22	1.69±0.24	1.73±0.27	1.73±0.28	1.73±0.28	1.73±0.28	1.74±0.28	1.80± 0.32
2	1.55±0.07	1.57±0.08	1.57±0.06	1.62±0.13	1.63±0.13	1.63±0.11	1.67±0.15	2.09± 0.31
3	1.59±0.16	1.63±0.15	1.63±0.17	1.70±0.15	1.71±0.17	1.71±0.18	1.72±0.18	2.08± 0.32
4	1.57±0.18	1.63±0.15	1.64±0.12	1.69±0.13	1.73±0.16	1.73±0.16	1.73±0.15	2.16± 0.34

The height growth of saplings starts from uneven values, with the lowest growth rates of V₂ and the highest – that of the control. However, at the end of the second year after treatment (5.10.2017) control is overtaken by all other variants, except for V₂, which began to grow from the lowest rate. At the end of the third year, this difference melted and in 2018 all of the fertilized saplings of all variants outran the control in height, although the control had the best growth indicators in the beginning of the studied period. Table 8 shows the increment in height during the investigated period.

Table 8. Current increment in height (m) in 2016, 2017 and 2018.

Variant	2016	2017	2018
K	0.10	0.03	0.07
1	0.10	0.09	0.06
2	0.12	0.13	0.42
3	0.11	0.13	0.36
4	0.14	0.16	0.43

Only V₁ ('Siapton' at a very low dose) showed a lower increment in comparison with control during all years. Obviously, at this low dose, the effect of fertilization is neglected and almost zero. In the other variants, a growth rate is in times greater than that of the control – for

example, 0.43m growth in 2018 for V_4 (fertilized with two organic fertilizers), against 0.07m increment of the control for the same year.

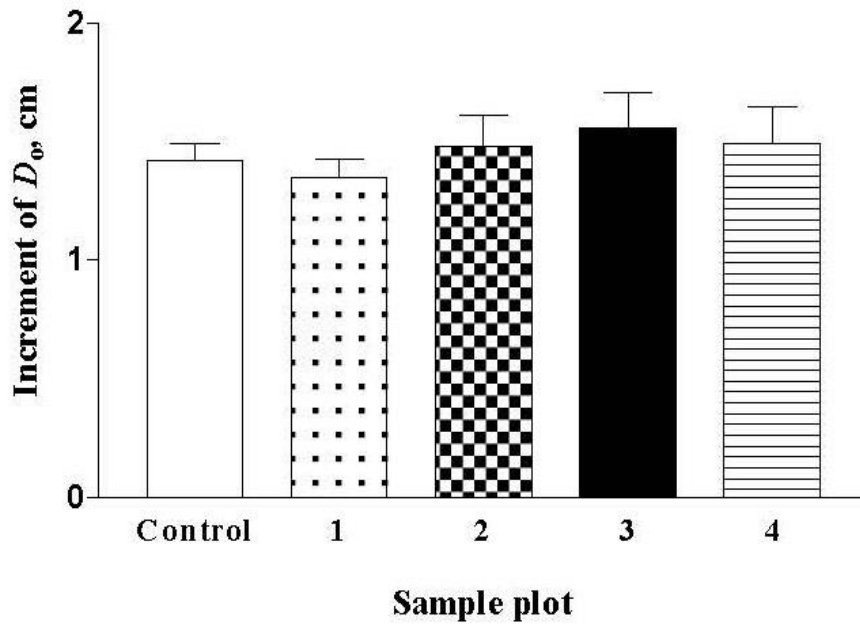


Fig. 1. Increment of D_0 during 2017–2018.

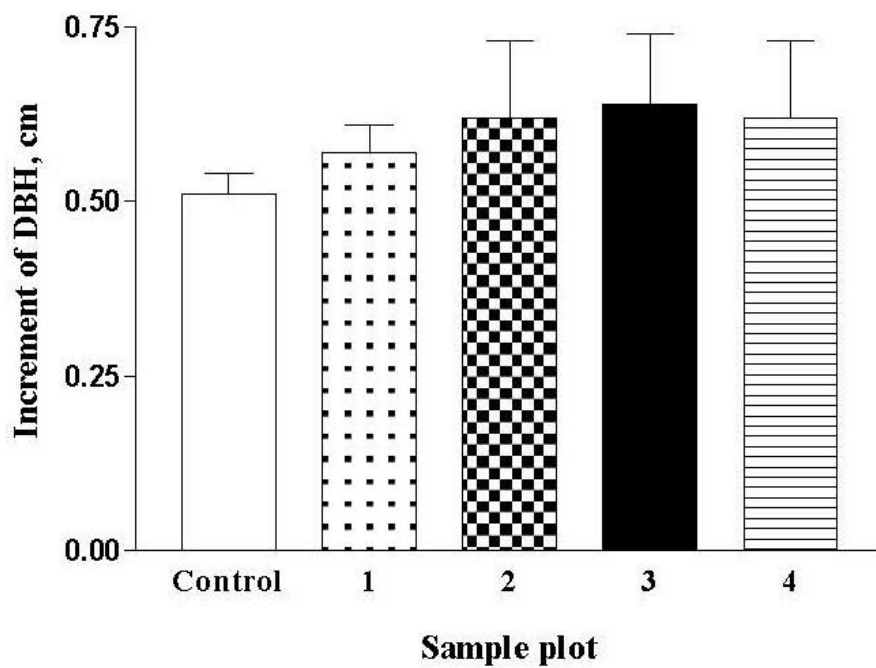


Fig. 2. Increment of DBH during 2017 – 2018.

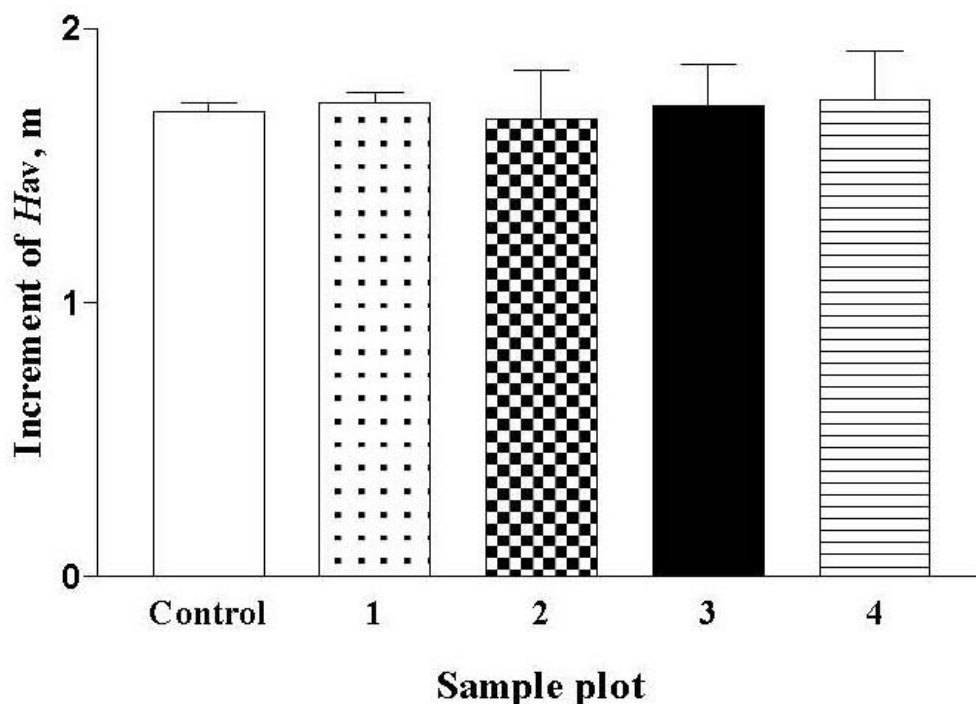


Fig. 3. Increment of Hav during 2017 – 2018.

The best growth rates of height in the three years after application of fertilizers show variants with organic fertilization: V_1 – high doses ‘Siapton’ and V_4 – combination of ‘Siapton’ with ‘Biohumus’. Especially high is the growth of saplings fertilized with high doses in the third year (2018). Obviously, the effect of fertilization – organic and mineral is prolonged and long lasting.

Due to close growth rates, statistical analyzes indicate a lack of statistically proven differences for all tested dendrometric indicators. In all cases $P > 0.05$ – no statistical significance. In Figures 1, Figure 2 and Figure 3 are presented the differences in the increment of D0, DBH and Hav over the months of 2017 – 2018. We have also computed some of the stem form coefficients (Table 9).

There is a difference in the coefficients that are indicators of the stem form. The closer to 1 is coefficient, the more cylindrical is stem. It is only coefficient q calculated according to the mean height that has clearly higher results for the fertilized variants in comparison with the control. The higher this coefficient is, the closer it is to 1, the thinner and the higher is the stem. All fertilized variants show better results for thickness and height of saplings compared to those of the control.

Regarding the total volume of biomass, the following results were obtained, shown in Table 10.

Table 9. Stem form coefficients in the end of 2016, 2017, and 2018.

Variant	2016	2017	2018
$q_0 = d_{\text{RCD}}/d_{1.30}$			
K	2.87	2.79	2.70
1	3.01	2.36	2.32
2	3.27	2.49	2.11
3	3.33	2.47	2.29
4	3.74	2.43	2.23
$q_2 = d_{1/2}/d_{1.30}$			
K	1.74	1.67	1.56
1	1.85	1.55	1.38
2	1.98	1.63	1.24
3	2.05	1.63	2.13
4	2.26	1.57	1.29
$q = d_{\text{RCD}}/H_{\text{av}}$			
K	0.28	0.30	0.32
1	0.0030	0.0033	0.0036
2	0.0029	0.0036	0.0038
3	0.0030	0.0037	0.0039
4	0.0025	0.0036	0.0036

Note: q_0 , q_2 и q are stem coefficients calculated as followed: $q_0 = d_{\text{RCD}}/d_{1.30}$; $q_2 = d_{1/2}/d_{1.30}$; $q = d_{\text{RCD}}/H_{\text{av}}$.

Table 10. Total volume (m^3/ha) in the end of 2016, 2017 and 2018.

Variant	2016	2017	2018
K	0.10	0.11	0.13
1	0.13	0.17	0.19
2	0.12	0.21	0.28
3	0.14	0.22	0.31
4	0.12	0.22	0.29

In all fertilized variants, larger tree biomass stocks are obtained, compared to the control. During the second year of fertilization, V₂, V₃, V₄ show high, almost equal, results for the biomass accumulation. In the third year, however, V₃ ('Sonton' with mineral fertilizer) is particularly well in relation with the accumulation of biomass – it outpaces nearly 3 times the yield of biomass in comparison with that of the control – 0.31 m^3/ha against only 0.13 m^3/ha for the control.

Discussion

The results show that organic fertilization has a strong positive effect on the growth performance of Norway maple saplings. It improves their diameter and height growth and biomass accumulation. The first condition for fertilizing, however, is the fertilizer dose. We found that at low doses the effect of fertilization is practically reduced to zero. At optimal doses, however, this effect is strongly expressed. Organic fertilizers greatly enhance the height and diameter at breast growth of saplings. In combination with two organic fertilizers this effect is even more pronounced. It is also a good combination of organic fertilizer with mineral, but here the effect of fertilization is shifted over time and is more pronounced after the second year of fertilization. Stronger in the third year, especially in biomass accumulation, is the combination with mineral fertilization, whereas only organic fertilization weakens its effect over time.

Secondly, after the dose, the effect of fertilization is mainly determined by the deficiency of trace elements in the soil (Zhelyazkov and Markova, 1993). In our case, the soil (*Vertisol*) is well-stocked (on average) with carbon ($\approx 4\%$), but is poorly stocked with nitrogen ($< 0.15\%$). We actually improve the soil conditions by introducing the necessary additional amounts of digestible nitrogen, which also improves the growth indicators of the tree saplings. There is sufficient evidence in the literature about the influence of mineral fertilization on woody plants. Denev (1966) demonstrates the positive effect of hyperphosphate, which increased the saplings growth in height, diameter, above ground and

underground biomass. Donovan et al., (1975) found the positive effect of mineral fertilization on the growth of Scots pine saplings and their photosynthesis due to improved metabolism. Fertilization with N, P and K leads to a strong increase in the absorption of these macronutrients, especially of N, which are mobilized in the soil as a result of the intensification of the microbiological activity (Dakev and Badjov, 1975). Significant increment of height and mean diameters is also noted by Tsanov and Broshtilova, (1986) in the fertilization of various branches of poplars. It is noted that improved mineral nutrition prolongs the growth period of saplings, and this is also observed by us where in fertilized variants the leaves fall a little later (unpublished data). The data presented in this publication is consistent with studies on the composition of soil microorganisms in the experiment with Norway maple saplings (Kachova et al., 2017). The best results of the ratio of heterotrophic microorganisms, actinomycetes, bacteria digesting mineral nitrogen, microscopic fungi and cellulose-digested microorganisms are found in V₃ (combination of 'Siapton' with mineral fertilizer) (Kachova et al., 2017). It should be noted that also better results than controls are available for organic fertilizer variants. However, the question of the impact of organic fertilizers on the growth of tree plants remains unclear. We show that it is particularly beneficial for the height growth of saplings.

Data obtained in this study show that the effect of fertilization is long-lasting and is observed strongly in both second and third year of treatment. Investigating the consequence of the mineral fertilization of saplings, Denev (1966) notes that the impact of the imported additional quantities of N and K lasts for 4–6 years. Here, too, we have a long-lasting influence on fertilization over time, with some differences being observed – the effect of mineral fertilization is increased and the effect of organic fertilization is diminished. However, the impact of organic fertilization is manifested over a longer period and the growth performance is better than the control. It is possible to expect the impact of fertilization with organic fertilizer 'Siapton' and in the next 4–6 years, by improving the height and diameter growth and total biomass stock.

With regard to the influence of the density and scheme of planting on crop productivity, the experience is unified. The main difference in the experiment is mainly due to differences in fertilization (organic, mineral) and in the fertilizer dose used.

Conclusions

The experiment with fertilization of *Acer platanoides* saplings with organic fertilizer 'Siapton' shows that fertilization has a favourable effect on the growth of saplings. This increases their average diameter, height and biomass in comparison with non-fertilized variant (control). Combination with other mineral and organic fertilizers strengthens the positive effect on growth indicators. The highest values of the diameter at breast height are in case of self-fertilization with organic fertilizer 'Siapton'. The best growth of saplings in diameter at the root collar in a long-term period (in the third year) is observed in the joint fertilization of organic fertilizer and mineral fertilizer. This combination is also best for the accumulation of woody biomass from saplings in a longer time period. However, for height growth of saplings, the combination of two organic fertilizers: 'Siapton' and made by red California worm fertilizer – is the best.

In general, we can conclude that the applying of fertilization with organic fertilizers when aiming a rapid growth and accumulation of biomass of Norway maple saplings is recommended for both urban environment and forest nurseries. The method is effective and is investment, which is paid out in the future.

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Problematic and Risks of Agricultural Activity in Fragile Environments Case of the Administrative Territory of Mila Province, Northeast Algeria

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Abstract

This study examines the approach of two contradictions in agricultural activity. The former is between the imperativeness of using agricultural technology as a necessity to overcome natural obstacles and secure the increasing food needs. The latter is, however, between the imperativeness of protecting natural resources as a guarantee for global and sustainable development. This is through investigating the effects and manifestations of environmental degradation in the administrative region of the province of Mila, which turned out to be an excellent agricultural field with considerable agricultural areas and enormous water resources. However, it poses the problem of exploiting these natural resources due to terrain obstruction and climatic conditions. Diagnosis and exploitation of available natural resources, agricultural activities, practice, and inputs of agricultural technology used in production enabled us to record several observations on the threats to fragile agricultural and ecosystems. Through field research and treatment of physical and chemical analyzes of surface water in three different areas of study, it turns out that the latter know several aspects of environmental degradation, including water and soil pollution, biodiversity degradation, groundwater depletion, in addition to soil erosion and its contribution to the mudding of the largest dam in Algeria.

Key words: agricultural activity, agricultural technology, fragile environment, environmental degradation, soil degradation, sustainable agricultural development

Introduction

Researchers, who adopt a scientific perspective, are forced to stand at the outputs of the effort exerted by the Algerian state in the agricultural and rural sectors, embodied in the application of successive agricultural and rural policies since the beginning of the third millennium in order to achieve food security and promote the national economy on the one hand, and to achieve regional balance and social justice on the other from the environmental side and their repercussions on the economic and social aspects. In light of the development of the relationship between man and his environment which became mutually in the influence and Impact after using agricultural technology classified by Ashraf (2019) into five main groups: mechanical technology, biotechnology, chemical technology, infrastructure

technology and finally regulatory technology. He also stressed that their use would increase the quantity and quality of agricultural and attains highest level of quantitative and qualitative satisfaction of humans.

While other experts recommend the use of agricultural technology as a necessity to go beyond natural determinism, Whether due to constraints that impede the easy and proper exploitation of natural resources as a terrain barrier, or because of limited natural resources just as Gintaras (2016) stated.

Other experts warn against the Dangers of relying on methods and technologies for improving agricultural productivity without taking into account the principles of achieving sustainable development. These dangers consist in the degradation of soils and the death of living things caused by the chemical technologies, thus an imbalance in the ecosystem including the cultivated area (Savci, 2012; Rainer, et al., 2019). Moreover, Air pollution and soil loss generated by the mechanical technology due to faulty and repeated plowing which stimulates the erosion (Kern et al., 1993), and heavy watering leading to the soil salinity (Zalidis et al., 2002). Finally, current and future risks arising from the use of Antibiotic Use in Agriculture and Its Impact on the Terrestrial Environment and the resulting genetic leakage (gene flow) put the biodiversity on the line (Kumar et al., 2005).

Jean-Luc et al., (1999) asserted that citizens in France are rejecting some options of agricultural production techniques; especially those do not guarantee both quality and safety.

FAO (2011) declared that over the last half century, intensive input-based agriculture has increased global food production and average food consumption per person. However, this process has depleted the natural resources of many agricultural ecosystems, posing a threat to future productivity and an increase in greenhouse gases that cause climate change.

Considering this variation in the influence and Impact of these agricultural inputs and cultivated environments, we discussed this study in the context of examining the contradictions between the inevitability of using agricultural technology as a necessity to overcome natural obstacles and secure the increasing food needs, and the imperative of protecting natural resources as a guarantee for inclusive and sustainable development, by trying to answer the following questions: Is this variation in the influence and Impact caused by variation in the characteristics of agricultural ecosystems? Or is it caused by the type and quantity of inputs of agricultural technology?

Our selection of the administrative province of Mila as a sample of our study was motivated by the diversity of its relief units and highlighting the geomorphologic impediment of northern Algeria, the fact that it represents a problem of the deterioration in the physical environment (the density of rills and gullies, Sliding soil, Water erosion), the depletion of its natural resources due to wrong agricultural practices and stimulating natural barriers, as well as being a vital media (Beni Haroun Dam 1000 Hm³, Hamam Grouz Dam 45 Hm³) which should be protected from environmental risks whose consequences may be of regional aspects.

1. Materials and Methods

To answer the problem, we discuss three main axes in this study:

1.1. Diagnose the natural resources available for agricultural exploitation

1.1.1. Tools and data used

Topographic map of Sidi Marouane and Sidi Driss 1/50000, Topographic map of Constantine 1/200000, Geological map of Constantine 1/50000, Land Occupation map 1/150000, Map of dry months (Moubarki, 2005), Digital elevation models (DEM), Notes Field search, Geographic Information Systems.

1.1.2. Methodology

- Create and analyze of DEM to identify homogeneous zones, and to identify homogeneous subzones.

- Extract of the natural and physical characteristics of homogeneous subzones after matching several maps; classify them according to the cohesion of the land into four categories, as shown in Table 1.

- To deduce the region's agricultural capacity in terms of natural resources and the extent to which it can be exploited in agricultural activity.

Table 1. *Indicators of sensitivity of the medium*

		Stable	Moderately Stable	Unstable	Fragile
Indicators	Slope (%)	0-3	3-12,5	12,5-25	>25
	Lithology	Gneiss+ Dolomite+ Sandstone	Clay	Quaternary Formations	Marl+ Gypsum
	Pluviometry (mm/y)	500-700	700-800	800-1000	>1000 / <500
	Land Occupation	Forests+ Fruit trees+ protection trees	Pastures+ Miscellaneous crops	Large-Scale	Undeveloped Land

1.2. Diagnosis of agricultural activities practiced and their risks to the environment

1.2.1. Tools and data used

Data and statistics of the Directorate of Agricultural Services (DAS) for the agricultural season 2010/2017, Directorate of Water Resources (DWR) 2008/2017, National Water Resources Agency (NWRA) 2007/2017, National Agency of Dams (NAD) 2014, Forestry Governorate(FG), 5th General Census of Population and Housing (RGPH) 2008, N°537/43.National Water Plan (NWP), carried out by the Ministry of Water Resources in 2005. The information and observations collected during the field outputs of farms and agricultural investors.

1.2.2. Methodology

After the collection and processing of statistical data were analyzed according to the inductive approach, where the risk of agricultural activity was evaluated by simulating the methodology of agricultural environmental indicators (AEI), the aim of AEI approaches is to characterise the environmental impact of a farming system from a set of indicators (Payraudeau and van der Werf, 2005).

1.3. Highlighting the environmental impact of agricultural activity and its economic and social dimensions

- Surface water pollution: by tracking the evolution of the concentrations of Oxydable Organic Matter (OOM), nitrogenous material (NM), Phosphorus Material (PM), for water from Beni Haroun Dam(BHD), Ouad Endja Valley(OEV), Hammam Grouz Dam(HGD), and

based on the quality standards set by the World Health Organization (WHO, 1994), we classified water quality into four categories.

- **Groundwater depletion:** by analysing the statistics of the Directorate of Water Resources and field research.

- **Biodiversity:** By linking some evidence with scientific facts and analysis of water and soil quality, in addition to the results of field investigation and comparison with the results of previous studies.

- **Soil degradation:** based on the analysis of the values of studies that have been studied and evidence from the field and linked to the subject of our study.

- **Dam miring:** Based on the results of measurements of studies of the BHD and the HGD (The Detailed Project Study (DPS) was conducted from 1983 to 1986 by an American study 'HARZA Engineering Company, U.S.A.').

2. Results and Discussion

2.1. Location, nature and relief

The study area is astronomically between two longitudes (06 ° and 34 minutes) and (05° and 45 minutes) east of the Greenwich line, and between two latitudes (36 ° and 37 minutes) and (36 ° and 53 minutes).

Geographically, it is located in the north-eastern part of Algeria, limited by the Numidian chain from the northeast and the Atlas series from the northwest, and the Upper Plains of Constantine from the south and southwest, make up the most important part of the large hydrographic basin of Kebir Rhumel No. 10, it includes the Babur Basin No. 03 in the far north and the Basin of the Constantine Plains No. 07 in the south.

Administratively, it is bordered by the wilayas of Skikda and Constantine on the north-east and Jijel on the north-west, bordering Oum el Bouaghi on the southeast, Setif on the southwest and Batna on the south (Figure1).

Its longitudinal extension over a distance of more than 80 km from the Atlas chain that follows north to the upper plains south highlights the topographic and climatic diversity of this area, Through the DEM Analysis, three homogeneous zones and 16 Homogeneous subzones (Figure 2a+2b) were identified :

- **Northern zones:** high mountain range.
- **Central zones:** internal plains, hills, and slopes of mountains.
- **Southern zones:** upper plains group.

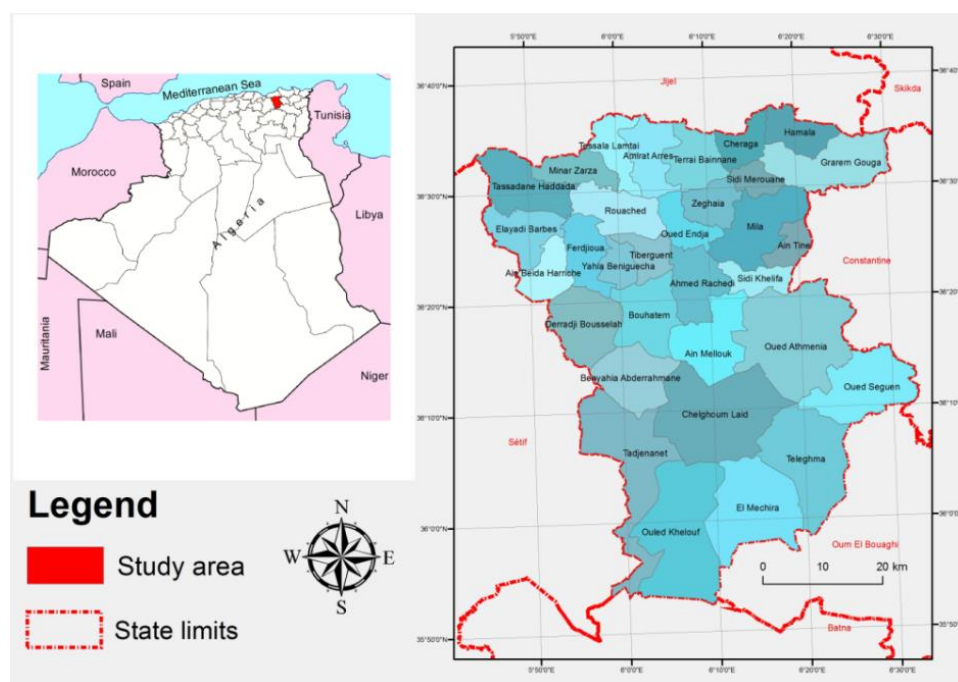


Figure 1. Location of the study area

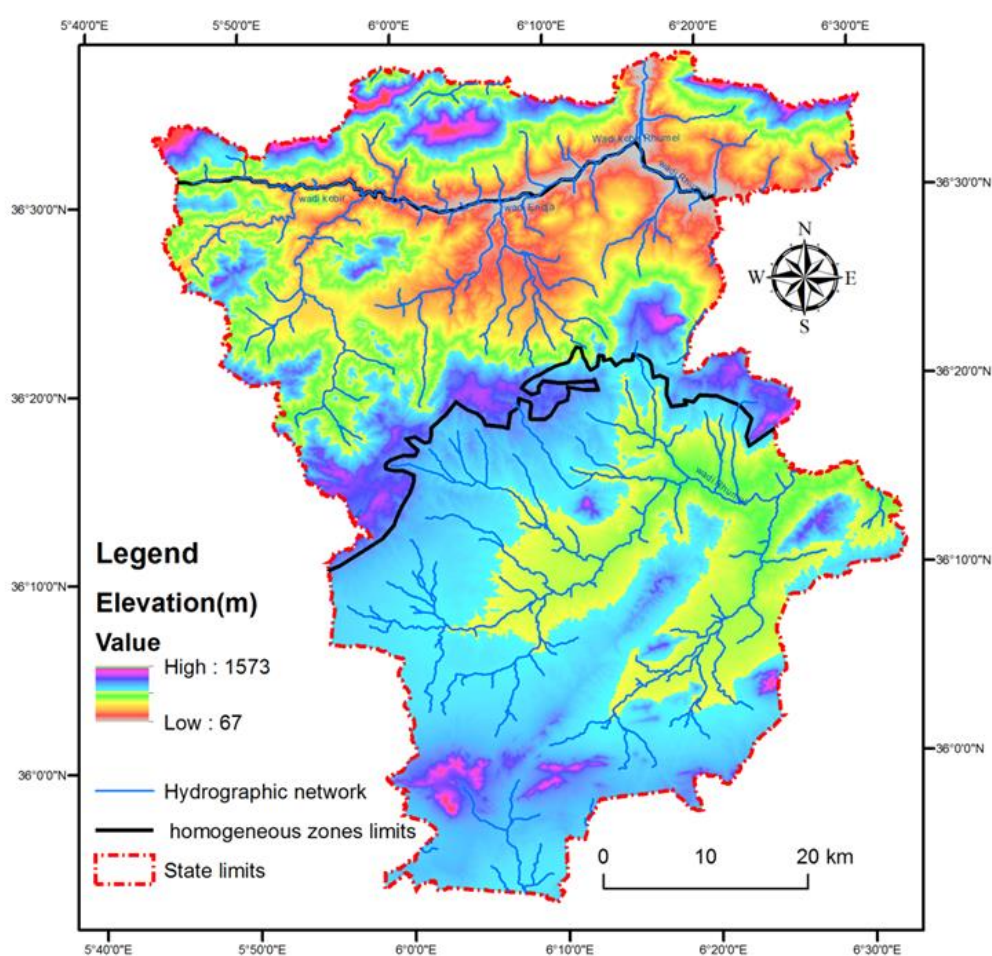


Figure 2a. Elevation map and hydrographic grid

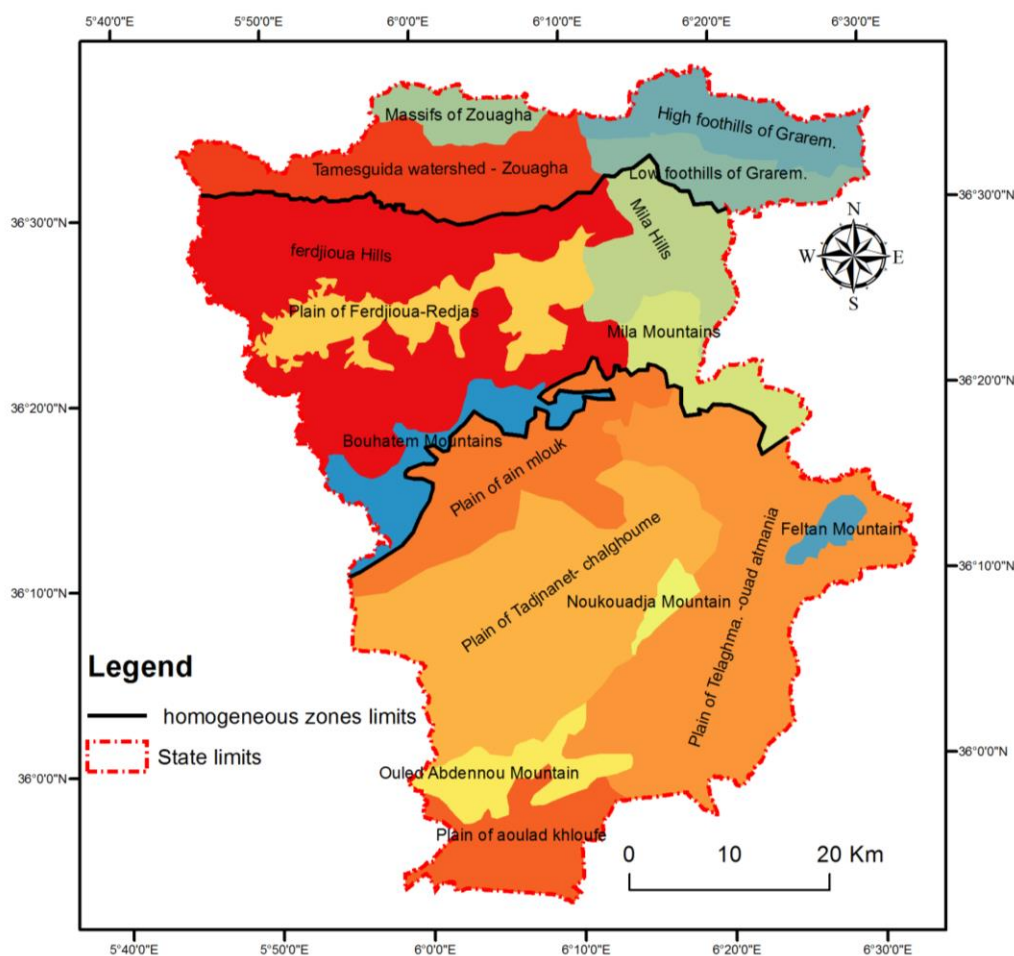


Figure 2b. Borders of homogeneous zones and sub-homogeneous zones

2.2. Available natural resources and possibilities of exploitation

2.2.1. Farmland

The study area covers an area of 348045 ha, of which 275,957 ha of arable land is equivalent to 79.28%, and 39,788 ha of forest land equivalent to 11.43% according to DAS 2017, Matching Figure 3 with available maps and field output observations, enabled us to identify The natural and physical characteristics of homogeneous subzones and their classification according to the soil stability into four categories as shown in Table 2 and Figure 3, and record the following results:

- 54.37% of the land is fragile and unstable, dominated by soft formations such as Marne and fourth time formations, in addition to clay formations, sandstone, conglomerate, etc. Its exploitation generates the processes of water erosion, slipping and grooving of the soil.

- 45.63% of the agricultural land is stable and of high quality, mostly located in the southern zone where the average rainfall does not exceed 500 mm annually and this limits the possibility of agricultural exploitation, and imposes the use of agricultural technology to overcome the climatic impediment.

- 74% of the territory of the northern zone with slopes of more than 25%, a mountainous populated area with very difficult social and economic conditions, which imposes the practice of agricultural activity.

- Only 1% of the land in the northern zone allows agricultural intensification.

- 38% of the central zone with steep slopes of more than 25% impedes the use of mechanical technology.
- Only 20% of the territory of the central zone allows the practice of agricultural intensification.
- 87% of the southern zone is suitable for agricultural intensification.
- The slopes of the central and northern zones drain all rainwater into the valleys, thus it cannot be utilized during the drought period.

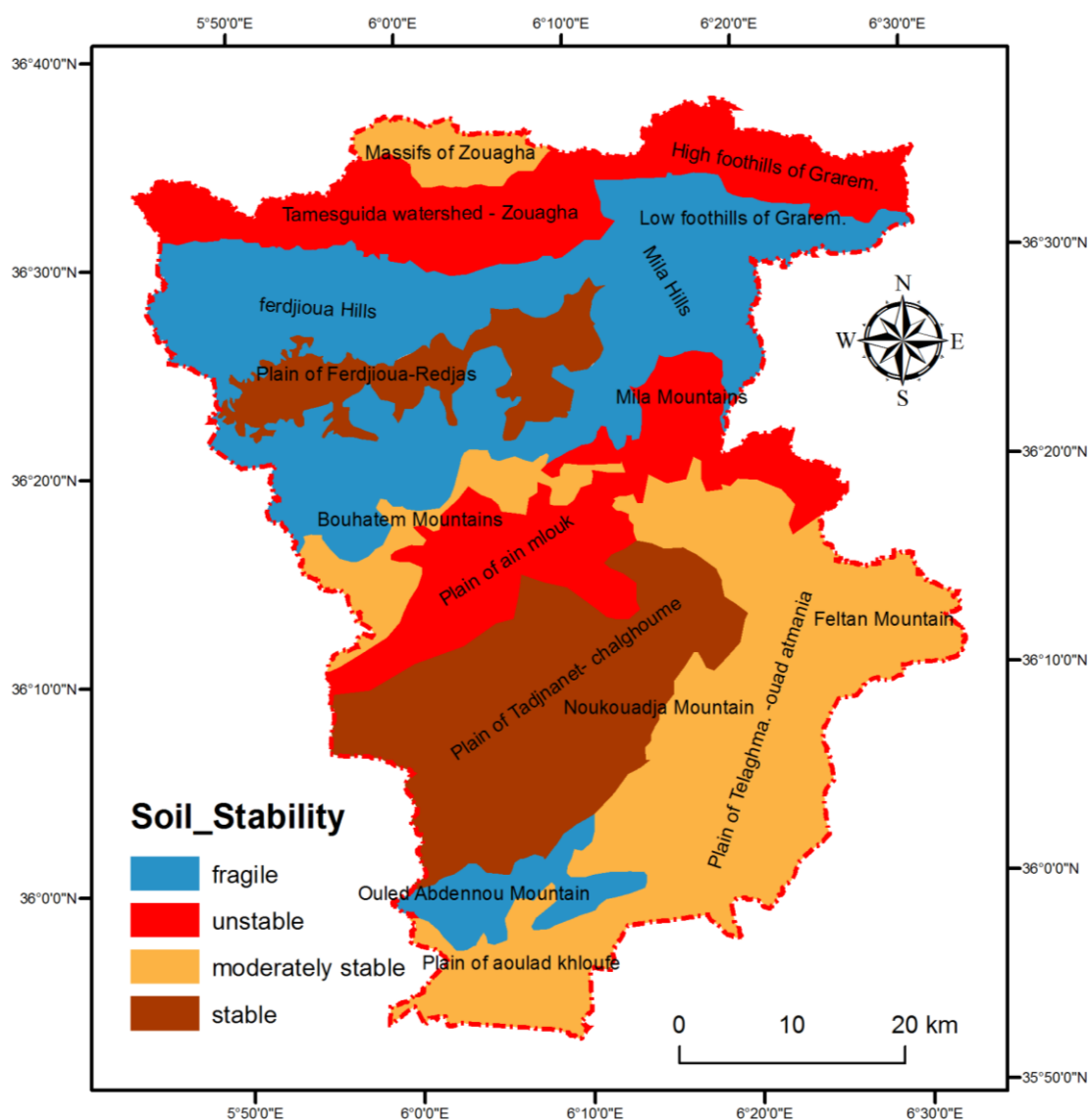


Figure 3. Soil Stability

Table 2. Summary of characteristics and potentialities by homogeneous subzones

		Homogeneous subzones	Area (Ha)	Slope (%)	Lithology	Climate Pluviometry (mm/y)	Land Occupation	Soil Stability
homogeneous zones	Northern zone	Massifs of Zouagha	6887	> 25	Gneiss+ Sandstone	Cool, Humid >1000 4 Months of Dryness	Forests + Mountain Pastures	Moderately Stable
		Tamesguida watershed - Zouagha	25736	> 25	Conglomerate+ Dolomite + Marl	Cool, Humid >800	Forests + Pastures+ Mountain Agriculture	Unstable
		High foothills of Grarem.	14668	12,5-25 > 25	Dolomite+ Marl+ Gypsum	4,5 Months of Dryness	Forests + Pastures+ Mountain Agriculture	Unstable
		Low foothills of Grarem.	10736	3-25	Marl+Clay+ Gypsum		Large-scale Agriculture+ Irrigated Agriculture	Fragile
	Central zone	Mila Hills	16330	3-25	Marl+Clay+ Gypsum	Sub-humid 500-800 5 Months of Dryness	Large-Scale Agriculture+ Pastures	Fragile
		Mila Mountains	11027	12,5-25 > 25	Marl+ Gypsum		Traditional Farming+ Pastures	Unstable
		Plain of Ferdjiousa-Redjas	18397	0-3	Quaternary Formations+ Marl		Intensive Farming	Stable
		Ferdjiousa Hills	61993	12,5-25 > 25	Marl+ Gypsum+ Dolomite		Large-scale Agriculture	Fragile
		Bouhatem Mountains	11407	> 25	Marl+ Clay+ Gypsum		Pastures	Moderately Stable
	Southern zone	Plain of Ain Mlouk	26381	3-25	Quaternary Formations+ Clay		Large-scale Agriculture	Unstable
		Plain of Telaghma.-Ouad Atmania	61859	0-3	Quaternary Formations+ Gypsum	Semi-arid 300-500 6 Months of Dryness	Intensive Farming+ Large-scale Agriculture	Moderately Stable
		Plain of Tadjnanet-Chalghoume	55744	0-3	Quaternary Formations+ Gypsum+Marl		Intensive Farming+ Large-scale Agriculture	Stable
		Plain of Aoulad khloufe	15121	0-3	Quaternary Formations		Intensive Farming+ Large-scale Agriculture	Moderately Stable
		Feltan Mountain	2588	12,5-25 > 25	Marl+ Gypsum		Traditional Farming+ Forests	Moderately Stable
		Noukouadja Mountain	2172	12,5-25	Gypsum+ Hard Dolomite		Forests + Pastures	Moderately Stable
		Ouled Abdenou Mountain	9757	12,5-25 > 25	Alluvium, Sand, Limestone + Hard Dolomites.		Forests + Undeveloped Land	Fragile

2.2.2. Water resources

Given that the location of the study area is within the most important part of the hydrographic basin kebir Rhumel, It is considered to be a large water reservoir because of the flows and the nature of its geological storage, a catalyst to expand the agricultural area and the practice of agricultural intensification in the flat southern zone. Table 3 represents the volume of water resources available in the state.

Table 3. *The volume of water resources available for exploitation in agricultural and social development.*

Water Resources		Place	volume of Water(Hm3)	Uses	Supply
Superficial	dam of Beni Haroun	Central zones	1000	Drinking	Six neighboring states
				Irrigation	irrigation perimeter of teleghma
	Dam of Hammam-Grouz	Southern zones	45	Drinking	States of Constantine
				Irrigation	States of Mila
	Dam of Sidi Khalifa	Central zones	70	Reserve reservoir for the dam of Beni Haroun	
Groundwater	929 Wells 306 Deep Well	Central zones +Southern zones	45,79	Irrigation	Agricultural lands in the central and southern zones
Water Barrages	4 Water Barrages	Central zones	1,53	Irrigation	Agricultural lands in the central zones
Natural Sources	-	Northern zones+ Central zones	10,67	Drinking+ Irrigation	-

Despite this important amount of water exceeding 1000 hm³, the possibility of exploitation remains the biggest obstacle for farmers for several reasons, including:

- The absence of large-scale watering systems has complicated the exploitation of reclaimed surface water in the BHD and the irrigation of large agricultural areas in the southern zone.
- Teleghama irrigation perimeter, which came into service in 2018 an area of 4447 ha, is currently directed only to supplementary watering of cereals.
- Competition for water by industry and household items, where the three dams of the state are part of the system of diverting water from the BHD to several states in the northeast and the upper hills.
- The water of HGD located in the southern zone is intended to supply the province of Constantine with drinking water, in addition to being exposed several times to pollution in 2013, 2014 and 2017.
- Non-renewable groundwater resources and over-exploitation put them at risk of depletion.
- Surface water is susceptible to contamination by wastewater and industrial wastes, considering the source of the important valleys “Wadi Kebir” originating from the

governorate of Setif, “Wadi Rhumel” which originates from the Ferdjioua mountains and passes through Constantine before flowing into the BHD (Mebarki, 2000); Thus, the exploitation of watercourses in irrigation during the scarcity period poses a threat to the ecosystem.

2.3. Practiced agricultural activities and their risks to the environment

The statistics of RGPH 2008 classified Mila as rural considering its rural population, which represents 57.16% of its total population. 25 Of the 32 municipalities are rural with agricultural activities dominated by agriculture and animal husbandry.

The population density is concentrated in the north with 246 inhabitants / km², 219 inhabitants / km² in the center and 77 inhabitants / km² in the south. This heterogeneous distribution of the population and the difficult socio-economic conditions that impose the exploitation of all agricultural areas require an examination of the agricultural practices nature, their distribution, as well as the techniques used in production in order to identify their risks to the environment.

2.3.1. Type and size of agricultural investments

Approximately 90% of the total arable area is exploited by 17158 agricultural investors of varying sizes and means of production, including:

- 86% of private sector investors, with small properties of less than 5 h; the family inherited from the ancestors and its production system horticulture, especially concentrated in mountains foothills situated in both the northern and central zone.
- 12% of individual and collective agricultural investments, an ancient pattern of exploitation of state-owned land under the policy of restructuring socialist farms in 1987; Individual agricultural investments are prevailing in the central zone with an average of 9h on the farm, and collective investments in the southern zone with an average of 117 h.
- 2% of the investments of reclamation through concession, a new pattern for the exploitation of state -owned land within the framework of the National Plan for Agricultural Development, concentrated especially in the northern mountainous zone.
- 10 model farms their functions are to modernize, to develop agricultural production, to produce seeds and to provide agricultural outreach.

The remaining 10% of the arable land represents agricultural areas without ownership titles (sub-tribes' lands) and their unregulated exploitation. This disparity in the pattern, size, and distribution of agricultural investments was imposed primarily by natural conditions namely the terrain and the climate, In addition to the land ownership system and the social conditions of the mountain population. As stated in the Agriculture Directorate statistics 2010, 16579 different sized and heterogeneous farms were registered. The classification of these farms into five categories based on the size criterion enabled us to compare the number of these farms and the total area which occupied by each category with the number and the total area of all the farms (table 4), and to put the following observations on record:

Table 4. *Classifying farms into categories of different sizes, according to 2010 statistics.*

Size of farm (Ha)	< 5	5-10	10-20	20-30	30-40	≥ 50	Total
Number of farms	7512	3529	2617	1111	829	981	16579
%	45	21	16	7	5	6	100
Area of farms (Ha)	18000	33940	75034	29252	22891	115185	294304
%	6	12	25	10	8	39	100

- 45% of the farms under 5 h represent only 6% of the total farms' area, mostly private property in the northern mountainous zone where the inhabitant's harsh social conditions making them exploit their small properties throughout the seasons in order to achieve Self-sufficiency, however, this intensive exploitation contributes to the depletion of limited natural resources, and frequent soil flipping causes water erosion and thus degrades agricultural land.

- 6% of the farms exceed 50 h, representing 39% of the total area of farms, including 3% collective agricultural investments in the southern zone, where appropriate terrain and soil quality allow the practice of agricultural intensification. However, the absence of large irrigation systems forces the practice of rainfed agriculture. This is the only type of cultivation that can impoverish soil fertility and expose it to the risk of erosion and desertification. In addition to economic and social risks in the event of deterioration of production, either due to climatic conditions or because of diseases and epidemics known to this type of agriculture.

- 49% of the medium-sized farms (5 - 40 h), occupying 55% of the total area of farms and distributed in the central and southern zones on the finest agricultural land, play a pivotal role in raising and developing agricultural production in several divisions such as cereals, garlic, and milk, but the special and individual style of these investments, the liberal-oriented agricultural policy adopted by the Algerian state, is mortgaging this development in future production. Considering that the peasant has complete freedom to run his land according to the Islamic Sharia system (the right of inheritance and intercession) which results in divisions and fragmentation each time until they become small property does not allow the introduction of mechanical technology (Bassoud, 2003).

- Expanding the agricultural area in the northern mountainous areas by rehabilitation and granting semi-forest land under the concession law leads to a reduction of grazing area and thus discourages animal husbandry. Moreover, a change in the nature of the ecosystems of these lands causes an environmental imbalance.

- The freedom granted to peasants in their agricultural investments makes some of them use irrational means and techniques that would have very serious environmental repercussions; the field research revealed that some peasants use valleys for irrigation without control, in addition to the use of poultry residues as fertilizers in a floodplain near the Lake of the BHD.

2.3.2. Crop agricultural pattern

The cultivation of cereals accounts for almost half of the agricultural area used during the 2016-2017 season 237557 ha. Fodder, fruit trees, vegetables and dry legumes did not exceed one fifth of the remaining area used as natural pastures.

Cereal cultivation is concentrated mainly in the central zone with semi-humid and in the Southern zone with semi-arid climates, and in small areas in the humid northern zone, which is predominantly fruitful in addition to various subsistence agricultures in the form of gardens imposed by difficult economic and social conditions. Although this distribution is imposed by the relief nature and climatic conditions prevailing in the zone, the continuation of this exploitation would prevent the possibility of achieving sustainable agricultural development for the following reasons:

- Dependence on large-scale cereal cultivation, although this is a national priority strategy, it is Rainfed agriculture in the absence of a large irrigation system; Thus, Its fluctuating returns due to drought or epidemics do not ensure that the increasing demand of the population is met creating economic and social risks.
- Frequent plowing in the cultivation of cereals in the central zone stimulates the erosion processes and consequently the deterioration of the natural environment, in addition to the risk of contamination with pesticide residues used in the treatment of diseases that affect this product every year.
- The reduction of vegetables cultivation area and dry legumes in very narrow areas compared to the area of cereals, leads to production limitation; Thus the failure of the wilaya of Mila in agricultural tasks Assigned to it in these divisions with wide consumption and high monetary value.

2.3.3. Watering technique and water sources

The percentage of irrigated area for the agricultural season (2016-2017) 5.61% of the total agricultural area used (Figure 4), which means that rainfed agriculture depends on rainwater, although it will expand this season after the opening of an irrigation area in Teleghma to irrigate another 4447 hectares in the southern zone by adopting a large irrigation system and benefit from the water of the BHD. As illustrated by the values of Figure 4 and the investigated field outputs, the following observations are made:

- The agricultural sector has little access to the water of the BHD and the absence of large-scale irrigation systems forces farmers to seek water for irrigation and depend on waterways.
- 19.42% of the irrigated areas come from waterways. This is really dangerous for plants, animals and humans in the first place (Okubo et al., 2019), especially the period of scarcity where water is less and the concentration of pollutants increases.
- The large hydraulic area for irrigation in the vicinity of Teleghma in the southern zone represents only 1.87% of the total agricultural area used, making these lands vulnerable to depletion.
- 80% of the irrigated area adopts a Sprinkler irrigation system, while the irrigation system Drip only 1% of the irrigated area. This results in a waste of water, although the pattern of large-scale cultivation leads to it.

•19% of irrigated area adopts surface irrigation system, which harms water consumption and stimulates water erosion.

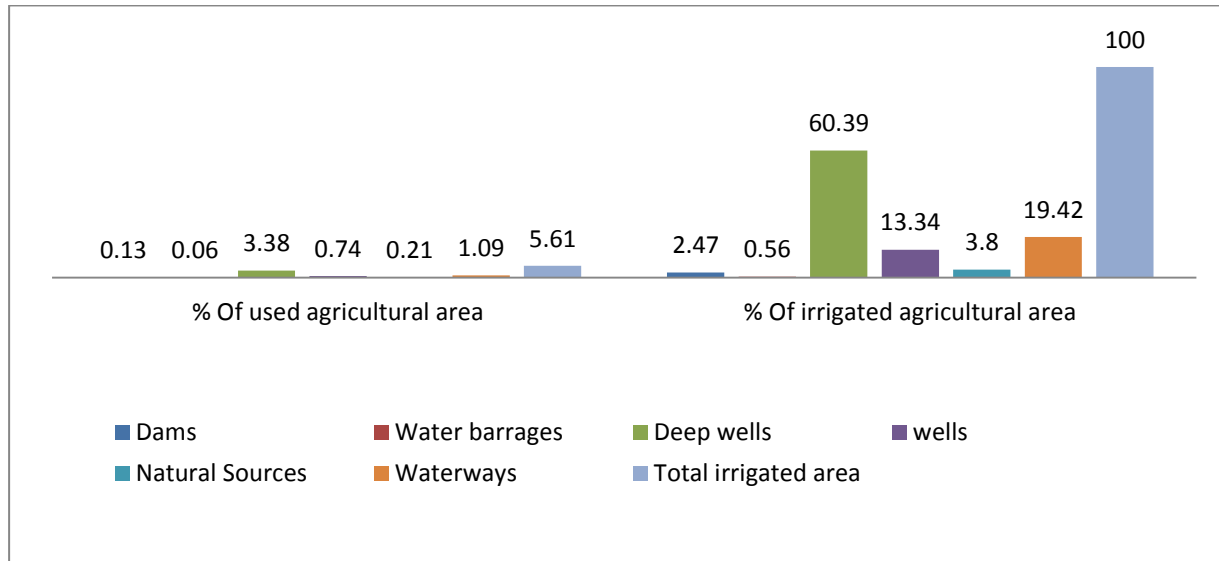


Figure 4. *Irrigated Area and Water Sources*

2.4. The environmental impact of agricultural activity and its economic and social dimensions

2.4.1. Water pollution:

Many water quality studies have found that this pollution is due to the deficit in the treatment of industrial wastewater, urban sanitation, As the Mebarki (2000) study concluded, but with the development of the use of chemical technology in agriculture (Figure 5), agricultural drainage has become a major contributor to the surface and underground water pollution (Skaggs, et al., 1994) where the residues of fertilizers, fungicides and insecticide contribute to changing the physical and chemical properties of water.

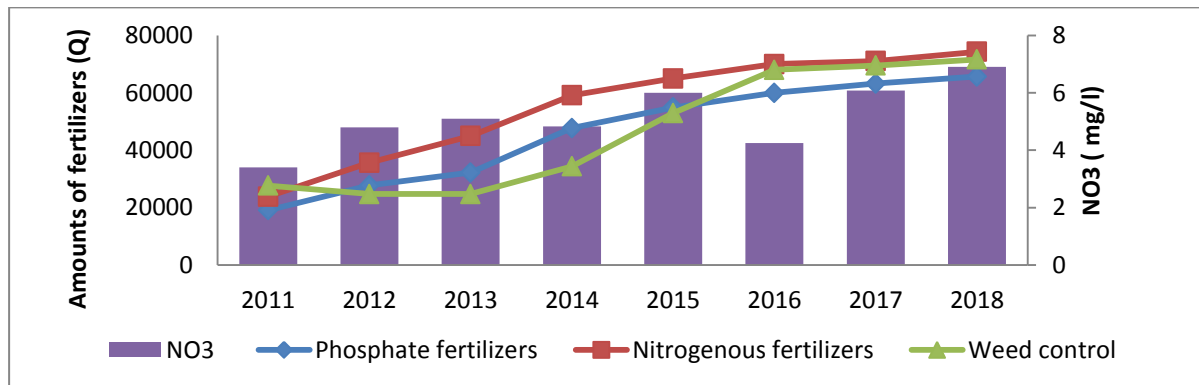


Figure 5. *Amounts of agricultural fertilizers used, and the temporal change of the average nitrate in the water of BHD*

The classification of surface water quality depends on the concentration of OOM, NM; PM (Table5) has enabled us to record the following results:

Table 5. Assessment of water quality based on the double-entry evaluation network, one by quality classes and the other groups of alterations.

Observation points	Different groups of alterations	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
OEV Code : 100252	OO.M	-	-	-								
	N.M	-	-	-								
	P.M	-	-	-								
HGD Code : 100315	OO.M											
	N.M											
	P.M											
BHD Code : 100620	OO.M											
	N.M											
	P.M											

Oxydable Organic Matter(OOM)= O₂diss or % Sat, MO, DCO, DBO5
 Nitrogenous Matter(NM)= NH₄⁺, NO₂⁻, NO₃⁻, NTK
 Phosphorous Matter (PM)= PO₄³⁻, P total
 Category1 in blue: good quality, usable without conditions.
 Category 2 green: moderate quality, the use of drinking requires simple treatment.
 Category 3 in yellow: poor quality, which requires focused treatment, for industry and agriculture.
 Category 4 in red: very poor quality, not usable until after very concentrated treatment.

• Very bad pollution of the HGD water, due to the high concentrations of OOM, and the significant concentrations of NM and PM. Rhumel valley is the main supplier of the HGD which stems from neighboring areas, and it crosses three municipalities (Tedjanet, Chalhoun Laid, Ouad Athmania as certainly the cause of this severe pollution is the accumulation of pollutants from wastewater (urban, sanitary, agricultural) of the three regions, considering that the industrial activities in these areas are almost non-existent, and the increasing use of chemical fertilizers (nitrogen, phosphorus) and pesticides (insecticides, fungi), In addition to organic fertilizers (animal residues, plant residues) in these zones, It certainly contributes significantly to the occurrence of this contamination, and this is consistent with the findings of study the Aissaoui (2013).

• Very bad pollution of OEV water, due to the high concentrations of OOM, and the significant concentrations of NM and PM, In the absence of industrial activities in the region, we believe that the pollution resulting from the increasing use of chemical fertilizers and pesticides used to treat diseases affecting agricultural crops every year, In addition to organic fertilizers from animal residues and harvest residues used by farmers as a natural fertilizer.

• Very bad water pollution of the BHD during the years (2010-2013); This is due to the pollution of the water valleys leading to the dam, Especially Wadi Endja and Wadi Rhumel Which passes on the neighboring areas, which witness a high population density and industrial activity and large agricultural.

• The water quality of the BHD has improved in recent years in terms of OOM and PM. We believe this is due to two reasons: One is that Wadi Rhumel water is being treated in several stations to improve its quality before it flows into the Lake of BHD, This corresponds to the Kerdoun (2016) study, The second is to reduce the concentrations of pollutants of Wadi

Endja and Wadi Rhumel when they meet the good quality water of Wadi Kebir. And the formation of wadi kebir Rhumel which forms the Lake of the BHD.

- In addition to industrial drainage, urban and health, agricultural drainage exacerbates the dilemma of pollution of the surface water of the Kebir Rhumel basin, And Loss of her quality that allows multiple uses, This would lead to an ecological imbalance in the area, As water is a vital element, it is necessary to take preventive measures and to allocate huge additional costs to treat and improve water quality.

2.4.2. Groundwater depletion

Unlike massive surface water resources, groundwater resources are weak at the state level, Estimated at only 45.79 Hm³ (DWR, 2018), it is Identified by the NAD 2006 study at 32 Hm³, The data of NWRA 2017 (Table 6) highlights lack of available groundwater resources for exploitation and the deficit in covering the actual needs of the population in the central zone.

Table 6. A comparison between potential groundwater resources and the actual needs of the population in several regions.

Regions	Resources potential (hm ³)	Actual needs (hm ³)	Resources available (hm ³)
Wadi Kebir	31.1	18.7	12.4
Wadi Endja	1.1	6.1	-5
Plain of Ferdjioua	1	6	-5.3

According to the data of DWR 2018, the number of wells used in agricultural activity reached is 929Well from 841 wells in 2014, Most of them are in the Upper Plains and according to field research, farmers in the region have assured us that the water level has dropped significantly in recent years. Which led them to dig an additional 50 meters to exceed the depth of 200 meters, after it was between 100-150 meters, Considering the number of wells used in industry and services, which reached only 61 wells in 2018, The groundwater depletion is certainly caused by excessive agricultural use.

The depletion of groundwater does not only mean additional costs for its extraction, It means that they are at risk of depletion which leads to the decline of vital and economic production in the region under the influence of the semi-arid climate factor (Berbel et al., 2018), This reflects negatively on the human factor and exacerbates the problems of unemployment and rural migration (Siebert et al., 2010).

2.4.3. Biodiversity

The BHD and HGD have known the phenomenon of fish mortality from the type of *Krasan*, especially in 2013, coinciding with the emergence of plankton with large areas surfacing, and the release of unpleasant odors, these are the consequences of eutrophication (Dovonou, et al., 2011; El Ghachtoul, et al., 2005; Horppila, et al., 2019). The residents of neighboring areas attributed this phenomenon to agricultural activity and considering the areas where fish mortalities occurred they were only meters away from fields with intensive irrigation and chemical technology, In addition to the practice of raising poultry in modified greenhouses near valleys pouring into the BHD, Kherief et al. (2018) confirmed that phytoplankton in the lake of BHD releases *cyanobacteria* with *neurotoxins*, Endangering fish and animal life and human health through the food chain.

On 04/07/2019, the public health services of the state announced that citizens from Rouached and Amirat Arres municipalities were infected with *malta fever* after consumption of cow's milk and goats. Without censorship, As the two areas overlook the Lake BHD and This period coincided with a shortage of valleys throughput and increased concentrations of pollutants, we believe that the cause of the disease is the germs carried by contaminated water.

Potato crops in the region have been exposed to dangerous *aphids* in recent years. According to a recent study by Aqueel et al., (2014), it confirmed that nitrogen-fertilized crops are an ideal environment for the breeding of this dangerous insect, and the proliferation of other harmful insects that feed on this *aphids*. This leads to disruption of food chain, and we believe that the spread of this insect is due to the increasing use of nitrogen fertilizers.

In an interview with the inhabitants of the northern zone, they asserted that the production of fruit trees has declined over the last ten years, and that fruit trees have become known from time to time serious diseases, which sometimes led to their loss. Especially *olive trees*, *vineyards* and *figs*, although most of them attributed the reason to the irregular rainfall, winds and the spread of diseases, we think that this is related to other reasons, including:

- The ecosystem of the BHD and HGD, in addition to the earthen dam reservoir of the BHD and the water barriers that contributed to changing the climate in the region to more humid; This explains the number and type of migratory waterbirds that have taken the path of the BHD for their commute, The winter inventory of migratory birds in 2017 was counted by the FG of Mila, 17401 birds. Among them are 12 new species in significant numbers, most notably the bird *fulligule nyroca* with a White neck and internationally protected, Its number is decreasing across the world, And Its significant presence of 348 birds enhances the region's fortunes to be classified as a wetland area under the 1971 Ramsar Convention.

- Use of biotechnology to plant fruit seedlings of exotic species in the region; In particular, *olive tree* seedlings, which were obtained by people in mountainous areas as part of agricultural support programs, and programs to protect the BHD from mud, which were supervised by the FG of Mila. In 2016, the area of fruit trees under agricultural support reached 7538.5 h. The area of protection trees is 6369 h, however, the yield is weak and we believe that these varieties do not suit the prevailing climate in the northern region.

2.4.4. Degradation and contraction of agricultural land

The diversity of the terrain and climate, and the different agricultural activities practiced between the north and south of the field of study, gave different manifestations and forms highlighting the degradation of agricultural lands such as water erosion, soil pollution, shrinking agricultural areas.

In terms of water erosion, or what is known as the erosion of the earth's surface and soil erosion caused by water, especially in the northern and central zones where the regression factor meets with the climate factor and the density of agricultural activity, And take several forms, Including diffuse runoff, Erosion by gully, Superficial slides, Sure, that Faulty tillage operations And Soil stirring using mechanical technology has a role in Decreasing the cohesion of the surface layer of slopes and hills And stimulate the dynamics of water erosion, which leads to the impoverishment of soil of organic and micro-materials, thus shrinking agricultural areas and declining quality, This corresponds to the Rotimi (2019) study.

In terms of soil contamination, Bouaroudj et al. (2018) indicated that watering on the shores of the BHD affects the physical and chemical properties of the soil, some samples had an excessive content of chloride bicarbonate and a high level of electrical conductivity in 39% of the study samples, leading to loss of quality productivity.

As a result of the 2006 Rural Renewal Policy, then the policy of agricultural and rural renewal in 2009, And embodied by the integrated rural development projects, Mainly rural housing, reducing agricultural areas in mountainous areas where small properties are exploited in gardening activities, resulting in the latter's decline.

2.4.5. Muddy dams

In addition to water erosion that reduces Agricultural area, the Surface materials and plankton swept by the flow of watercourses and valleys threaten the quality and quantity of water of the BHD and HGD, Mebarki (1982) estimated the Specific degradation in Athmenia Valley for the month of April in 1979 at 1.2 tons / km², and 17.9 tons / km² in Garam and 67.8 tons / km² in Tassadane, The NWP (2005) study also indicated that HGD is known as 0.6% of the mud per year.

The bathymetric campaign conducted by NAD (2014) recorded 83 hm³ volume of silt deposits at BHD, That is, a sedimentation rate of 8.3 hm³ / year, and the specific degradation was estimated at 1728 ton / km².

Compared with the results of study the DPS (1983-1986) that preceded the completion of the BHD, we concluded that the specific degradation is estimated at 1205 tons / km², This indicates an increase in the volume of sediment flow and plankton, and indicates a high Mud ratio in the dam, which was estimated at 0.62% each year.

Given the very high concentrations of organic matter in surface water, it is certainly because of these flows and what it carries of sediments and plankton. The agricultural activities in the central and northern zone undoubtedly play an important role in causing water erosion processes especially with the fragility and the brokenness of the land and the severity of its decline.

Conclusion

Based on research into the purpose and problem of this study, we draw the following conclusions:

The natural resources of agro-ecosystems used for the study are fragile with a heterogeneous distribution. Both flaws pose the problem of proper agricultural exploitation, and impose agricultural patterns adapted to terrain in general and climatic conditions in particular despite the environmental risks.

The use of agricultural technology inputs in the region is linked to the abundance and quality of natural resources; it aims at developing production rather than expanding agricultural land and bypassing natural constraints.

A clear lack of infrastructure technology that would enable the peasant to overcome natural inevitability and climatic conditions and create permanent jobs in the agricultural sector; for example: food and processing industry units in mountainous areas, and livestock investors in the northern zone, watering areas in the central zone, agricultural irrigation drainage systems in the central and southern zones.

The use of Agro-chemical technology has led to increased production in recent years, especially in some agricultural divisions. On the other hand, it has left many manifestations indicating environmental degradation and calling for urgent precautions to avoid the aggravation of the situation in the future eliminate the erroneous agricultural practices by private farmers.

Finally, we can emphasize that ensuring food security requires sustainable agricultural development which depends on the abundance quality and accessibility of available natural resources, further, the impact of the agricultural technology use on the cultivated and surrounding ecosystems.

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Prof. Dr. Ekaterina Georgieva Filcheva at 70 years old



Prof. Dr. Ekaterina Filcheva is a specialist on soil organic matter, founder and long-term leader of the Bulgarian Humic Substances Society (BHSS) - since 1997 till now.

She was born on 08/02/1949 in Sofia, Bulgaria. She graduated secondary school in 1967 Sofia, and 1972 - Sofia University "Kl. Ohridski", Faculty of Chemistry, Master on Inorganic chemistry. 1973-1976 she was a PhD student and December 1976 defended a thesis for the scientific degree and was conferred a degree of Candidate of Soil Sciences, (Dr.) titled "Complex forming ability of soil organic matter", N. Poushkarov Institute of Soil Science, Sofia, Bulgaria.

She has spent her career at the Institute of Soil Science "N. Poushkarov", department Soil Genesis and Classification. Her Habilitations were in December 1989 (Assoc. Prof.) and Prof. – December 2004 with Thesis "Comparative characteristics of soils in Bulgaria in content, composition and stocks of organic matter.

The main topics of her work are using of soil organic matter characteristics for soil diagnostics and classification purposes (Soil organic matter as a characteristic and criteria of soil types and subtypes); soil rich in organic matter (Histosols) and their classification; organic carbon reserves of Bulgarian soils; methods for soil organic matter determination; isolation of humic substances; mineralization and humification processes of waste materials and composts; soil organic matter complexes with heavy metals; soil quality, fertility and carbon sequestration - managing of humus formation; improving soil quality and increasing crop production using lignin, barks and peat composts or humus contained products; soil reclamation - initial humus forming processes of land affected by open mining processes; crop rotation and sewage sludge amendment on soil organic matter content and composition, soil and environmental quality.

During her career Prof. Filcheva performed three fellowships: Agricultural Research Center, Beltsville, Maryland, USA "Influence of enriched with Fe, Mn and Zn biosolids on the uptake of elements by plants", supervisor Rufus Chaney; EC Fellowship (N 5340), The Macaulay Land Use Research Institute Aberdeen, UK "Effect of pollution with heavy metals on the organic matter transformation", supervisor Martin Cheshire and NATO Fellowship at the Institute of Soil Classification and Mapping, Larissa, Greece "New approach for maintaining and management of soil humus in sustainable agriculture", supervisor Christos Tsadilas and participated in more than 15 International projects with Russia, Japan, Belgium, EC projects, USA etc.

Prof. Filcheva was a supervisor of a student from University of Forestry under "Students practice", Program of Ministry of Education and Science, 2014 and had lectures titled „Soil organic matter" under Project BG051PO001-3.3.06-0042, "Interdisciplinary

preparation and raised of qualification of young scientists in the field of soil science and ecology”, Lectures for the individual preparation of 3 scientists, 2014.

She was an active member and took part in the different Councils: Scientific Council of the Institute of Soil Science “N. Poushkarov”; Expert Council for Soil Science, General Agronomy and Melioration at the National Center for Agricultural Sciences and Agricultural Academy (2007-2014); Specialized Scientific Council for Soil Science, Agro chemistry and General Agronomy at the Highest Testimonial Commission -2007-May 2010. She is a member of Bulgarian Soil Science Society and Union of Soil Science, national Coordinator for Bulgaria of IHSS, President of Bulgarian Humic Substances Society (BHSS) ESSC- till 2015; Bulgarian Historical Agricultural Society.

During her carrier Prof. Filcheva was a board member of several Journals: “Soil science, Agrochemistry and ecology”; Journal of Ecological Science “Ecology and Future”; J. “Balkan Ecology”; Journal “Geosciences Report”; Editorial-in-Chief of World Research Journal of Agricultural Sciences; Assoc. Editor of Journal „Geochemical Exploration” and a reviewer of several International journals. The administrative responsibilities in her long career at the Institute of Soil Science Prof. Filcheva was Head of laboratory “Soil organic matter” in the N. Poushkarov Institute of Soil Science (1986 – 1993); Scientific Secretary of the N. Poushkarov Institute of Soil Science and Head of the section "Scientific potential, Coordination of Scientific activity, and International activities (05.01.2004 – 11.12.2008) and Head of Department “Soil genesis, geography and classification” (10.11. 2011- 02.3. 2015).

She helped in the organization of two Conferences of N. Poushkarov Institute and Soil Science Society with International Participation, 2005 and 2007. She is the main organizers of four Conferences of Bulgarian Humic Substances Society (BHSS) with International Participation: 2000, 2003, 2011, and 2016. The most important event of Bulgarian Humic Substances Society (BHSS) was 19 Meeting of IHSS, 2018 with 178 participants of 30 countries in Albena resort, Bulgaria she was the main responsible scientist and organizer. BHSS hosted this important Meeting of IHSS devoted to Humic Substances and Their contribution to the climate change mitigation.

Prof. Filcheva has 250 publications includes outstanding work on important problems in agriculture and ecology with 2 books in English; Terminology dictionary; 5 chapters in book (2002), 2 chapters in the books: - 2004, 5 - 2005, 3 - 2006, chapter in Proceeding “Sustainable Land Management” (2007), 6 chapters in a book - 2014, Journals, including impact journals, Proceedings in conferences, congresses, 1 dissertation, 1 Habilitation Thesis; and 2 invention Certificates, 242 citations of 95 publications (index h=5). Her monographs published in 2007, 2015 and 2017 presents the most complete database and assessment of the soil organic matter of the main virgin, cultivated soils and under forest for their characteristics and grouping and as criteria of soil fertility of Bulgarian soils, and role of soil organic matter in contaminated with heavy metals soils.

Prof. Filcheva is well known scientist in the field of soil science, especially soil organic matter, soil organic matter characteristics for soil diagnostics and classification purposes - soil organic matter as a characteristic and criteria of soil types and subtypes, soil rich in organic matter (Histosols) and their classification; organic carbon reserves of Bulgarian soils; composts etc. She has detailed fundamental investigations on soil organic matter of Bulgarian soils. Prof. Filcheva studied the changes in quality and quantity of soil

organic matter under different soil tillage system, crop rotations, fertilization of the main soil types of agricultural lands of Bulgaria. She collected own and published data on soil organic matter of Bulgarian soils: arable, under forest and virgin, and using Packet Statistica, she published generalized (statistically) profiles of the main soils of Bulgaria, profile distribution of soil organic carbon, humic and fulvic acids along the profile depth. The main soils of Bulgaria are included in the following groups, according to the soil organic matter composition (Ch/Cf): Izohumic saturated, Izohumic unsaturated, Texture differentiated, Hydromorphic, Shallow and weakly developed soils; Grouping of the main soils of Bulgaria according to soil system stability into three groups: the highest stability to the changes virgin to arable lands have Calcic and Epicalcic Chernozems; Vertisols, Haplic Chernozems are included in the middle group and the Pseudopodzolic soils in the lowest stability.

Some of her publications with co-authors were devoted to the influence of modified zeolite on the carbon sequestration in flooded soils, agricultural practices for soil carbon sequestration, model approach to improve soil quality using organo-zeolite compost, modeling soilforming processes in artificial zeolite soils. Part of her works is focused on the methods of organic carbon determination, humic acids characteristics, characterization of humic system in fertilizer raw materials; quantitative and qualitative characterisation of humic products with spectral parameters; chemical and instrumental methods for investigation of soil organic matter.

Prof. Filcheva has worked with famous world wide scientists as Prof. J. Beck, Prof. Martin Haigh, Prof. Martin Cheshire, Rufus Chaney, Prof. Richard Arnold, Prof. Christos Tsadilas, Prof. Slaveiko Krastanov, Prof. Todor Boyadgiev, Prof. Svetla Gencheva etc.

She participated personally in scientific Congresses and Conferences abroad as 14th and 16th Congresses of Soil Science in Kyoto, Japan and Montpellier, France; 1st Central Asia Congress on Modern Agricultural Techniques and Plant Nutrition, Kyrgyz-Turkish Manas University (KTMU), Bishkek, Kyrgyzstan, 6th Meeting Of IHSS, Bari, Italy and 10th Meeting of IHSS Toulouse, France, 14th Meeting of IHSS in Moscow-Sang Petersburg, 17th Meeting of IHSS Ioannina, Greece Main organizer of 19th Meetings of IHSS, 1st, 3rd and 4th Congresses of Turkish, chapter of IHSS, Turkey, 11 Conference of Polish chapter of IHSS; Conferences Adana, Turkey, Barcelona, Spain, Chalkidiki, Greece, Bucuresti, Romania, Kavala, Greece, 3 Conferences on Carbon Sequestration in USA; 2 papers published in São Pedro, 12th Meetin of IHSS São Paulo, Brazil, 3 papers in the 13th Meeting of the IHSS, Karlsruhe Germany, .and 1 paper in 14th Meeting in Moscow, 3 papers in the 17th Meeting of IHSS, Ioannina, Greece and many Conferences and workshops held in Bulgaria.

Prof. Dr. Ekaterina Filcheva retired from the Institute of Soil Science “N. Poushkarov”, 23 August 2015 after more than 42 years investigations in the same Institute. She has still published papers and books in the scientific journals.

Happy Anniversary Prof. Filcheva

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Website: <http://bhss.itp.bg>

Prof. Metodi Teoharov

President of Bulgarian Soil Science Society

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Journal articles

- Atanassova, I., S. Doerr, 2010. Organic compounds of different extractability in total solvent extracts from soils of contrasting water repellency. *European Journal of Soil Science*, 61, 298-313.
- Calderón, H. W., 1982. The content and composition of humus in arid alluvial soil of Peru. *Soil Science, Academy of Sciences of USSR, Moscow*, 8, 53-59. (in Russian).

Books

- Sparks, D. L., 2002. *Environmental Soil Chemistry*, 2nd Edition, Academic Press, San Diego, CA.

Book chapters or conference proceedings

Petrova, R., 1989. Loss of Humus Soil in the Process of Reclamation of Damaged Terrains. In: N. Sherbanova, R. Nacheva (Eds.). *Proceedings from Fourth National Conference on Soil Science 'Problems of Soil Science in Intensive Agriculture'*. BSSS, N. Poushkarov Soil Science and Yield Programming Institute, Sofia, 203-206, (In Bulgarian).

Online publications

Atanassova, I., S. H. Doerr, 2011. Changes in Soil Organic Compound Composition Associated with Heat-Induced Increases in Soil Water Repellency. *European J. of Soil Science*, DOI: <http://10.1111/j.1365-2389.2011.01350.x>

Dissertations and Philosophy Doctor Theses

Hristova, M., 2013. content and availability of microelements-metals in Technogenic soils. Ph.D. Thesis. Agricultural Academy, ISSAPP 'N. Poushkarov', Sofia, 140. (In Bulgarian)

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